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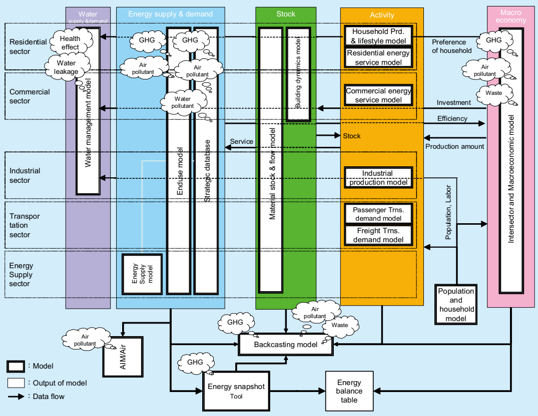
Aligning Climate Change and Sustainability

- Scenarios, modeling and policy analysis -

Asia-Pacific Integrated Modeling Team



Vision A	Vision B
Vivid, Technology-driven	Slow, Natural-oriented
Urban/Personal	Decentralized/Community
Technology breakthrough Centralized production /recycle	Self-sufficient Produce locally, consume locally
Comfortable and Convenient	Social and Cultural Values

Center for Global Environmental Research

National Institute for Environmental Studies, Japan

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Aligning Climate Change and Sustainability

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Aligning Climate Change and Sustainability: Scenarios, modeling and policy analysis

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Foreword

The Center for Global Environmental Research (CGER) at the National Institute for Environmental Studies (NIES) was established in October 1990. CGER's main objectives are to contribute to a scientific understanding of global change and to identify solutions for pressing environmental concerns. CGER conducts environmental research from interdisciplinary, multi-agency, and international perspectives, provides an intellectual infrastructure for research activities in the form of databases and a supercomputer system, and makes the data from its long-term monitoring of the global environment available to the public.

In April 2006, CGER launched its new climate change research program as one of the four priority initiatives forming the crux of the current five-year research plan at NIES. One of the core research projects of the climate change program involves developing visions for a low-carbon society (LCS) and performing an integrated analysis of climate policies. As a part of this project, we held the first workshop of the Japan-UK Joint Research Project on Developing Visions for a Low-Carbon Society through Sustainable Development in June 2006 and the AIM training workshop for aligning climate change and sustainability in October 2006. This report is a set of documents and manuals which were prepared for the AIM training workshop, in order to describe examples of future visions and scenarios of achieving LCS and sustainable development (SD) and to give instruction on how to use modeling tools to assess future scenarios of LCS and SD.

We hope this publication contributes to research on the global environment; in particular, the achievement of a Low-Carbon Society and sustainable development through international co-operation leading to the mitigation of future climate change.

January 2007

Yasuhiro Sasano

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Preface

An important characteristic of the climate system is its inertia. Because of past and current greenhouse gas (GHG) emissions, a certain increase in global temperature is unavoidable. Such increases in temperature carry profound risks. Even a small increase in temperature is likely to have significant impacts on ecosystems and species, and might lead to increased droughts and extreme rainfalls, with severe consequences for our society. There is a strong need for scientific findings regarding when and by how much emissions need to be reduced to achieve stable GHG concentrations. However, it cannot be achieved within a short span such as a few years or decades, and it is necessary to set a long-term goal guided by a desirable vision.

The objective of this report is to describe future visions and scenarios for achieving the goals of Low Carbon Society (LCS) and Sustainable Development (SD) and explain modeling tools to assess future scenarios of LCS and SD toward 2050. There is no silver bullet to achieve LCSs. A portfolio of options and international cooperation are necessary to realize global LCS. Aligning SD and climate change actions can reduce the burden and facilitate the transition to stabilization. In the near-term, the LCS actions will deliver multiple benefits if aligned with the Millennium Development Goals (MDGs). In the long-run, climate stabilization will require significant technological changes. Mainstreaming the development, transfer and deployment of low carbon technologies in national SD policies and actions will be the key to a cost-effective transition to LCS.

This report provides a set of tools and methods to assess the technical and market potentials of a variety of technology and policy options to realize LCS. The simulations have to keep in view the driving forces of energy (including demographics, economic growth, and resource endowments), land-use changes, and structural changes in the economies. The complexities of comprehensive, consistent and transparent analysis require use of formal modeling tools, strategic databases, and purposive methodologies to achieve optimal and robust results.

A set of tools in this report is part of AIM family models. AIM started in 1990 as a set of tools to evaluate policy options to mitigate climate change and its impacts, and subsequently extended its function to analyze other environmental issues such as air pollution control, water resources management, land use management, and environmental industry encouragement. It is intended to offer a platform for policy makers and researchers and to enhance communication among these communities. I sincerely hope that AIM tools will help to develop visions for LCS through SD.

January 2007

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Contents

List of Figures

Part I Aligning Climate Change and Sustainability

Part Ⅱ Energy Snapshot Tool Manual

Part Ⅲ AIM/Enduse Model Manual

List of Tables

Part I Aligning Climate Change and Sustainability

Part Ⅱ Energy Snapshot Tool Manual

Part Ⅲ AIM/Enduse Model Manual

PART Ⅰ

Aligning Climate Change and Sustainability

1 Introduction

1.1 Aligning climate change and sustainability

The twin challenges of climate change, mitigation and adaptation, are best addressed within the overall context of promoting Sustainable Development (SD). This section discusses the approaches to integrating mitigation and adaptation policies in SD strategies and making them mutually supportive, especially in the developing countries. The debate on relationship between climate change and SD is anchored on two perspectives. The conventional view emphasizes co-benefits of climate change mitigation and adaptation actions for SD goals such as improving local air quality or land conservation. The approach is to ensure that climate actions are not adversarial to local or national development goals. The alternate perspective views climate change from the lens of SD. It acknowledges that driving forces of emissions as well as adaptive and mitigative capacities are shaped by development paths.

This approach frames the debate from development priorities rather than environmental concerns and views the aligning of development and climate actions as an endogenous process of shaping the development path along the sustainable trajectory. Two key propositions underlying this approach are: *i. pathways to achieve SD goals are climate-friendly, and ii. SD is the driving force for addressing climate change challenges, especially in developing countries.* Under this paradigm, the transition to Low Carbon Society (LCS) could be best achieved by mainstreaming climate change agenda in development actions; and aligning these actions to shift the frontier of development and climate goals through innovations, co-benefits, focused technology and investment flows and aligned stakeholder interests. In many developing countries, national development policies are already capitalizing on synergies between development priorities and climate benefits. According to one study[1], six major developing countries (Brazil, China, India, Mexico, South Africa and Turkey) reduced their carbon emissions growth over three decades by approximately 300 million tonnes per year. Without these measures, their emissions would have been 18% higher in the year 2000. The annual emission reduction achieved is not far from being equivalent to the reduction that industrialized countries, including the United States, committed themselves to under the Kyoto Protocol.

In the near-term, the actions inducing transition to low carbon future in developing countries will deliver multiple dividends if aligned with the Millennium Development Goals (MDGs). An example of how the MDGs and related national targets in India can be complementary to climate agenda is shown in Table 1.1.1. In the long-run, the climate stabilization would require significant technological change; wherein aligning the development and transfer of low carbon technologies with the national SD policies will be the key to cost-effective transition to LCS.

Development Pathways and Emissions in IPCC Assessments

The IPCC Special Report on Emissions Scenarios and the Third Assessment Report (TAR) concluded that alternative development paths can result in very different greenhouse gas (GHG) emissions. Decisions about technology, investment, trade, poverty, biodiversity, community rights, social policies, or governance, which may seem unrelated to climate policy, may have profound impacts upon emissions, the extent of mitigation required, and the resulting cost and benefits. Development paths leading to low emissions are shaped by major

[1] Chandler W, Schaffer R, Dadi Z, Shukla PR, Tudela F, Davidson O and Alpan-Atamar S (2002), Climate Change Mitigation in Developing Countries, Report, The Pew Center on Global Climate Change, Washington DC, October.

policy choices in areas other than climate change. A country's development path has a large effect on mitigation cost and can be as important as an emissions target in determining overall costs. Conversely, climate policies that implicitly address social, environmental, economic, and security issues may turn out to be important levers for creating a sustainable world.

Climate-friendly Development Actions in Developing Countries in NATCOM Reports

Initial National Communications to the UNFCCC from key developing countries show contributions to mitigation and adaptation by actions motivated by SD goals like poverty alleviation, local environmental protection and energy security. In Brazil, for example, a national program to promote the substitution of gasoline by domestically produced alcohol as a vehicle fuel reportedly avoided emissions in the order of 400 million tonnes of CO_2 over the period 1975-2000, while at the same time offsetting imports of 550 million barrels of oil and reducing the demand for foreign currency. Mexico reports a reorientation of the national fuel policy during the period 1994-2005, which consists in reducing the consumption of fuel oil and increasing that of natural gas, with a considerably lower CO_2 emission factor. South Africa's *White Paper on Renewable Energy and Clean Energy Development* sets a target for renewable energy contribution to final energy consumption by 2012 which aims at considerably increasing the current share of renewable, thereby reducing GHG emission growth. China's National Communication provides information on a wide range of adaptation measures in such fields as water conservation and management, flood protection, adjustment of agricultural structure and cropping systems and forest protection. The fact that many climate-friendly actions in developing countries originated from non-climate development priorities provides ample evidence in support of mainstreaming climate interests within development strategies in the future development of the climate regime.

Why to align Development and Climate Actions?

It is advisable and feasible to mainstream climate concerns into evolving development perspective through an inclusive strategy that promotes the climate cause through innumerable economic development actions that happen daily and everywhere, rather than following the current strategy that marginalizes the climate cause by pursuing exclusive climate centric actions. Many key developing countries are now shaping their development paths and investing in back-bone infrastructures. Their near-term choices could create lock-ins similar to those observed in urban development patterns and transportation infrastructure in industrialized nations. Among the most important development choices with relevance to climate change are those made in the energy sector to provide modern energy services. Measures for promoting energy efficiency and renewable energy are common to SD and climate stabilization agendas. Within this wider and inclusive context, near-term instruments like CDM can play a complementary role.

How to align Development and Climate Actions?

All development actions offer opportunities to internalize climate externalities. For instance, the energy choices to deal with energy security risks in rapidly growing developing countries are intertwined with SD and the cost-effectiveness of global GHG stabilization regime. The enhanced use of domestic coal in China and India in the wake of sustained high oil price for mitigating the energy risks would increase their carbon emissions. On the other hand, the development of domestic hydro resources or nuclear power under international co-operation could reduce their emissions. For instance, as Fig. 1.1.1 shows, India's energy transitions over past five decade have been fossil energy (and therefore carbon) intensive, with secularly increasing penetration of coal, oil and gas and decline in share of biomass and hydro. The future energy choices could have vastly different energy security, emissions and development implications. Now, when India is on a very rapid growth trajectory, significant energy investments are being made and the future energy and carbon intensity would be decided by the choices in the near term and the lock-in effect on the future energy choices. Similarly, the electricity reforms in developing countries are leading to choices which have significant implications for aligning energy security, emissions and development benefits and also the associated lock-ins which would drive the future pathway.

SD, stabilization and energy choices

Among the most important development choices with relevance to climate change are those made in the energy sector. Increased access to safe energy and energy services can have several consequences for climate change, dependent on the pathway. Specifically in the field of energy, the policies for promoting energy efficiency and renewable energy are common to SD and stabilization agendas. Despite the needs for expanding their energy consumption for sustained economic growth, most developing nations have instituted policies to ensure cleaner and more sustainable energy future. These policy choices have a significant impact on energy trends, social progress and environmental quality in developing countries (Geller et al., 2004)[2]. Energy security is a precondition for sustainable economic growth. In India, so as in China and South Africa, coal is a major domestic energy resource. Instability in global energy market like energy supply disruptions or high prices of oil could make the energy system of these countries more coal, and hence carbon, intensive. Energy security in developing countries can be enhanced on the demand-side by improving energy efficiency and on the supply-side by enlarging the portfolio of domestic energy resources as well as access to regional energy resources. The proposed bio-fuel program in India (Planning Commission, 2003)[3] is an excellent example where multiple dividends can accrue in terms of energy security, sustainable local development and climate benefits of mitigation and adaptation.

In early phases of development, countries make investments in back-bone assets, i.e. the infrastructure on which additional investments are made for manufacturing and delivering goods and services. Infrastructure choices create lock-ins (Arthur et al. 1987[4], Ruttan, 2002[5]) for how human, technological and physical capital is deployed. The lock-ins creates path dependence, which is not apparent in the near-term. In longer term the bifurcation is more evident, however it is then too late and expensive to shift from the path (Hourcade, 1993)[6]. For instance, the transportation infrastructure in industrialized countries developed without explicit attention to energy security or climate change concerns. The past infrastructure decisions have created lock-ins into energy and emissions intensive pathway. Climate-friendly infrastructure choices are feasible in developing countries that are presently creating the

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[2] Geller, H., R. Schaeffer, A. Szklo, and M. Tolmasquim, 2004: Policies for advancing energy efficiency and renewable energy use in Brazil. *Energy Policy*, 32, pp. 1437-1450.

[3] Planning Commission, 2003. Indian Vision 2020, SP Gupta Committee Report. Planning Commission, Government of India, New Delhi.

[4] Arthur, W. B., Ermoliev, Y.M., and Kaniovski, Y.M., (1987), Path dependence processes and the emergence of macro-structure, European Journal of Operational Research, 30 (June):294–303.

[5] Ruttan,V.W., 1998, The new growth theory and development economics: A survey, Journal of Development Studies, 35:1–26.

[6] Hourcade J C. 1993. Modelling long run scenarios - Methodology lessons from a perspective study on a low CO_2 intensity country. *Energy Policy*. 21 (3). pgs. 309-25.

back-bones. A couple of decades of delay, in rapidly growing economies like China and India, to align the infrastructure choices towards low energy intensity and climate-friendly pathway could create adverse lock-ins.

Besides infrastructure choices, there are numerous other development policies and actions that could profoundly influence future energy use and associated emissions. The urban development is one key area. Differentiated structures of settlements generate widely differentiated emissions through transportation. Nivola (1999)[7] shows how divergent policies in Europe and the United States since 1945 have shaped widely different structures for cities, and in turn widely different demands for transport services, energy consumption (Newman and Kenworthy, 1991)[8], and CO_2 emissions. Financial policies, like differentiated taxes on gasoline, which are implemented for budgetary reasons and not for environment or climate change reasons have led, over the course of half a century, to higher energy efficiency of cars in Europe than in the United States, and therefore to lower emissions per passenger-km traveled. The 21st century will witness major urbanization in developing countries. Urban development choices would offer opportunities, those if wisely harnessed would deliver profound SD and stabilization benefits.

Co-benefits of aligning mitigation and adaptation actions

Climate mitigation and adaptation policies are most often not addressed jointly as they appear to belong to entirely different domains, mitigation being as a global public good and adaptation as a private good. Development though is the common determinant of both mitigative and adaptive capacities. There are numerous synergies and trade-offs between the adaptive and mitigative capacity elements of the socio-economic and natural systems, as well as between specific adaptation and mitigation policies. Building more highways, for example, can generate more traffic and more GHG emissions. However, highways can also improve market access, make agriculture less vulnerable to climate change, help in evacuation prior to big storms, and can support general economic growth and thereby investments in new efficient production technologies. The GHG mitigation potential and cost of energy efficiency policies for households and industry sectors depend on the dynamics of economic structure and policies vis-à-vis energy intensive industries, investments in new production facilities, and lifestyles of households. Similarly the vulnerability of resource dependent sectors to climate change and its impacts for the economy at large will depend on the extent of flexibility or lock-ins inherent in the structure of industry or the lifestyle of households. Integrated policies can maximize win-win opportunities.

Some areas where sustained co-benefits from integrating mitigation and adaptation actions can accrue are: i) biomass, land-use and unmanaged ecosystems, ii) water management, iii) agriculture, iv) energy for space heating and cooling, and v) design of long-life assets, like infrastructures. The biofuel program in Brazil has delivered direct mitigation benefits as well as indirect benefits like local employment and energy security that are vital for adaptation. In the forestry sector, opportunities for linking mitigation and adaptation exists in afforestation and reforestation projects like commercial bio-energy, agro-forestry, forest protection and forest conservation through sustainable management of native forests. Projects that help contain deforestation and reduce frontier expansion play important role in mitigation, besides

[7] Nivola, P.S., 1999: *Laws of the Landscape: How Policies Shape Cities in Europe and America.*Brookings Institution Press, Washington, D.C., USA, 126pp. 32

[8] Newman, P.W.G., and J.R. Kenworthy, 1991: *Cities and Automobile Dependence - An International Sourcebook.* Avebury Technical Publishing, Aldershot, U.K.

delivering developmental and adaptation benefits like protection of biodiversity and conserving watershed and soils.

In most developing countries, incomes of farming communities derive from rain-fed cultivation. The increased water stress due to the dual effects of unsustainable water consumption and climate change would make these communities more vulnerable. Sustainable water management projects like rainwater-harvesting, watershed development, drip irrigation, zero tillage, bed planting, multiple-cropping system, crop diversification, agro-forestry and animal husbandry are win-win-win solutions that deliver development, mitigation and adaptation co-benefits. In urban areas, sewage treatment is an important area for enhancing water availability while gaining co-benefits of methane recovery and associated mitigation.

Climate co-benefits from Regional Cooperation for Development

Regional cooperation between developing countries is another important strategy for SD that delivers mitigation and adaptation co-benefits. It allows more rational deployment of a region's human and natural and environmental resources while exploiting complementarities to achieve win-win-win outcomes in terms of development, adaptation and mitigation. For instance, an assessment of South Asia regional economic and energy cooperation shows that efficient energy trade could yield direct economic benefits (Heller and Shukla, 2005)[9], as better fuel and technology choices reduce energy consumption and investments in energy supply. The direct benefits would add 1% growth to the region's economy each year during the period 2010-2030. There indirect benefits would amount to 5.1 billion tonnes of cumulative CO_2 emissions mitigation (and concomitant SO_2 emission reductions) over the same 20 year period. In addition, spill-over benefits exist from enhanced water supply and flood control by additional hydro dams, and these would translate into adaptation benefits.

Strengthening international cooperation for aligning development and climate actions

Since the early 1990s, the international community has developed a number of multilateral instruments to address the problem of climate change. These include the United Nations Framework Convention on Climate Change (UNFCCC), which entered into force in 1994 and now has 189 Contracting Parties. It was complemented in 1997 by the Kyoto Protocol and in 2001 by the Marrakech Accords, a package of detailed rules for the implementation of this protocol as well as for the implementation of existing commitments under the UNFCCC relating to funding, capacity-building and technology transfer. The alignment of SD and climate actions in developing countries now requires the following:

1. Further developing the potential of market-based mechanisms;
2. Mobilizing additional financial resources for climate-friendly development;
3. Addressing adaptation more effectively;
4. Accelerating technology transfer to developing countries.

Evidently, the policies to meet national SD goals have important impacts on national GHG emissions and capacity to mitigate and adapt. The direction and magnitude of the changes vary depending on the policy and on national circumstances. Some general lessons that emerge are: i) in a country, the sectors that are farther away from the production frontier offer opportunities for multiple dividends by freeing resources to meet SD goals and in addition reduce GHG emissions and enhance mitigative and adaptive capacities, ii) national

[9] Heller T.C and Shukla P.R, 2005, Financing the Climate-friendly Development Pathway - with Illustrative Case Studies from India, Report 500019002/2005, Netherlands Environmental Assessment Agency, The Netherlands.

circumstances, including endowments in primary energy resources and institutions (World Bank, 2003)[10] matter in deciding the extent to which development and climate benefits are ultimately realized, iii) the win-win opportunities would diminish as markets and institutions get organized in time in developing countries; therefore global climate agreements in early periods should pay special attention to capture multiple dividends in the near-term and avoid lock-ins that cause path dependence towards high emission profiles in long-term.

Emissions pathways that can stabilize concentration, e.g. not to exceed 2 degrees temperature rise, are far below the unmitigated endogenous emissions pathways. Therefore, mitigation instruments designed to alter endogenous emission pathway at the margin would be ineffective and would cause excessive distortions. The future climate framework should be more effective if it can stimulate climate benign, non-climate actions that shape climate-friendly pathways. The opportunities can be taken up by existing businesses into innovative ventures, requiring the forging of coalitions between the mainstream policy agencies, civil society and private actors (Heller & Shukla, 2005). Within wider and inclusive contexts, in the near-term the marginal instruments like CDM can still play additional role as one of the instruments for aligning national SD strategies with climate objectives. Crafting policies and instruments that influence innumerable development actions would be a key to aligning development and climate interests.

The architecture of future climate regime should therefore aim for instruments that mainstream climate interests within development choices. A key lesson from scenario assessment is that climate agreements can deliver more if they view the climate problem from the development lens. Climate centric instruments are inferior to those which first support endogenous climate-friendly actions and then induce exclusive climate centric actions. The benefits of aligning development and climate actions would benefit all countries, though the welfare gains are more apparent in developing countries.

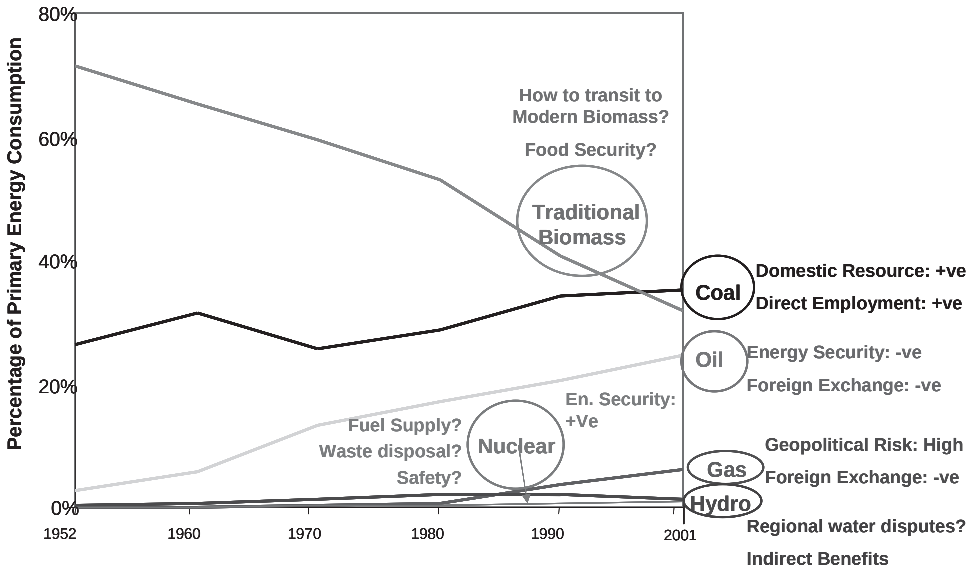

Fig. 1.1.1 Energy transitions and how they matter to low carbon future.

[10] World Bank, 2003. World Development Report 2003, Sustainable Development in a DynamicWorld, Transforming Institutions, Growth and Quality of Life. Washington D.C., USA, 250pp.

Table 1.1.1 MDGs, related Indian targets and climate change

MDG and global targets[11]	**India's 10th plan (2002-2007) and beyond targets**[12, 13, 14]	*How these address climate change concerns?*
Goal 1: Eradicate extreme poverty and hunger ***Target 1:*** *Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day* ***Target 2:*** *Halve, between 1990 and 2015, the proportion of people who suffer from hunger*	▪ Double the per capita income by 2012 ▪ Reduction of poverty ratio by 5 percentage points by 2007 and by 15 percentage points by 2012 ▪ Reduce decadal population growth rate to 16.2% between 2001-2011 (from 21.3% during 1991-2001)	▪ Enhanced adaptation capacity due to improved food security, health security and resilience to cope with risks from uncertain and extreme events
Goal 2: Achieve universal primary education ***Target 3:*** *Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling*	▪ All children in school by 2003; all children to complete 5 years of schooling by 2007 ▪ Increase in literacy rates to 75% by 2007 (from 65% in 2001)	▪ Enhanced adaptation capacity due to improved skills, flexibility to shift vocations/locations
Goal 3: Promote gender equality and empower women ***Target 4:*** *Eliminate gender disparity in primary and secondary education, preferably by 2005 and in all levels of education no later than 2015*	▪ At least halve, between 2002 and 2007, gender gaps in literacy and wage rates	▪ Enhanced capacity of women to deal with added social risks from climate change
Goal 4: Reduce child mortality ***Target 5:*** *Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate*	▪ Reduction of Infant mortality rate (IMR) to 45 per 1000 live births by 2007 and to 28 by 2012 (115 in 1980, 70 in 2000)	▪ Enhanced resilience of children to health effects of climate change due to improved access to health services
Goal 5: Improve maternal health ***Target 6:*** *Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio (MMR)*	▪ Reduction of MMR to 2 per 1000 live births by 2007 and to 1 by 2012 (from 3 in 2001)	▪ Enhanced resilience of women to health effects of climate change due to improved access to health services
Goal 6: Combat HIV/AIDS, malaria and other diseases ***Target 7:*** *Have halted by 2015 and begun to reverse the spread of HIV/AIDS*	▪ Have halted by 2007; 80 to 90% coverage of high risk groups, schools, colleges and rural areas for awareness generation by 2007	▪ Higher resilience of the population due to enhanced capacity to deal with epidemics ▪ Enhanced resilience to added risk of Malaria and

11 Human Development Report, 2003 (UNDP, 2003)

12 Planning Commission (PC, 2002a), Tenth Fiver Year Plan, Government of India, Vol. 1 (pp 6-8), Vol. 2 (pp. 108, 117, 909, 914, 927)

13 For the most recent year between 1985-1999 (UNDP, 2002), pp. 176

14 Planning Commission (PC, 2002b), India

Target 8: *Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases*	▪ 25% reduction in morbidity and mortality due to malaria by 2007 and 50% by 2010	other vector borne diseases
Goal 7: Ensure environmental sustainability ***Target 9:*** *Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources* ***Target 10:*** *Halve by 2015 the proportion of people without sustainable access to safe drinking water* ***Target 11:*** *Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers*	▪ Increase in forest and tree cover to 25% by 2007 and 33% by 2012 (from 23% in 2001) ▪ Sustained access to potable drinking water to all villages by 2007 ▪ Commission 14.4 GW hydro and 3 GW by other renewables in a total power generation capacity additions of 41.1 GW between 2002-2007 ▪ Electrify 62,000 villages by 2007 through conventional grid expansion, remaining 18,000 by 2012 through decentralized non-conventional sources like solar, wind, small hydro and biomass. ▪ Cleaning of all major polluted rivers by 2007 and other notified stretches by 2012	▪ Lower GHG emissions and local emissions; lower fossil fuel imports; reduced pressure on land, resources and ecosystems ▪ Higher adaptive capacity to climate variability due to enhanced water supply ▪ Resilience to cope with health impacts of climate change due to access to clean water and electricity ▪ Higher adaptive capacity due to enhanced reach of health/education facilities dependent on electrical equipments and flexibility of economic activities in rural areas
Goal 8: Develop a global partnership for development ***Target 12:*** *Develop further an open, rule-based, predictable, non-discriminatory trading and financial system (includes a commitment to good governance, development, and poverty reduction - both nationally and internationally)* ***Target 16:*** *In cooperation with developing countries, develop and implement strategies for decent and productive work for youth* ***Target 17:*** *In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries* ***Target 18:*** *In cooperation with the private sector, make available the benefits of new technologies, especially information and communications technologies*	▪ Expeditious reformulation of the fiscal management system to make it more appropriate for the changed context ▪ Tenth plan includes state-wise break up of the broad developmental targets. ▪ Higher integration with the global economy ▪ Create 50 million employment opportunities by 2007 and 100 million by 2012 (current back-log of unemployment is around 9%, equivalent to 35 million persons)	▪ Higher resilience to climate change due to enhanced supply of social infrastructure ▪ Higher mitigative and adaptive capacity from access to global resources and technologies ▪ Enhanced flexibility of jobs and migration ▪ Improved capacity to deal with health risks due to access to advanced medicine and health services ▪ Enhanced adaptive capacity to deal with extreme events from access to advanced information and communication systems

Note: Millennium targets13 and 14 refer to special needs of least developed, land locked and small island countries. India is party to several international conventions and programmes assisting these countries. India is also implementing policies in line with target 15 that exhorts amelioration of debt of developing countries, including own debt, under global cooperation.

2 Vision/scenario studies

2.1 Scenario approach and back-casting approach

2.1.1 Scenario approach

A long-term view of multiplicity of future possibilities is required to consider the ultimate risks of climate change, assess critical interactions with other aspects of human and environmental systems, and guide policy responses. Scenarios offer a structured means of organizing information and gleaning insight into the possibilities[15]. Researchers are often interested in exploring hypothesized interactions and linkages between key variables by using scenarios analysis. On the other hand scenarios can be utilized as part of a decision-making or planning process and for bridging the gap between the scientific and the policy-making communities. In such a case upcoming decisions need to be highlighted and different choices and their outcomes can be explored. Here the scenarios can be used in a more informative or educational way. Alternately, depending on the process employed, they can be used to challenge assumptions on the functioning of certain processes and illustrate different views held by participants in the scenario building exercise[16].

There are many definitions of scenarios in the literature. They differ a lot depending on the purpose of the scenarios and how they were developed. For example, the SRES report[17] defines the whole set of scenarios as 'alternative images of the future' used to explore future developments (in GHG emissions and their driving forces). SRES scenarios consist of two integrated elements, qualitative narratives (or stories) about the future and quantitative elaborations of these stories, based on formal modeling. These two elements together define 'an internally consistent and reproducible set of assumptions' about key driving forces, relationships and outcomes.

Scenarios are also characterized as 'exploratory' and 'normative'. Exploratory scenarios are those that begin in the present and explore trends into the future. Examples of these are the SRES scenarios. By contrast, normative scenarios start with a prescribed vision of the future (optimistic, pessimistic, or neutral) and then work backwards in time to visualize how that future could emerge[18]. Examples of these are the scenarios developed for the LCS analysis to be presented later. Sometimes 'exploratory' and 'normative' scenarios are used together to analyze the future world. Exploratory approach is used to see what can happen using the current set of technologies, while normative approach is used to give insights on what kind of technologies should be developed and installed by a specific period.

Another way to characterize scenarios is by baseline (non-intervention) and policy (intervention). The SRES are baseline scenarios based on four storylines expressing different views of future world development pathways, especially in the degree of globalization vs. regionalization and economic growth vs. environmental protection. The post-SRES scenarios are policy scenarios based on the SRES. These studies reveal that different developmental paths (baselines) require different technology and policy measures for achieving same levels

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[15] Morita et al. (2001) Greenhouse gas emission mitigation scenarios and implications, Climate Change 2001: Mitigation, Cambridge Press.

[16] Carpenter S.R. *et al*. (eds) (2005) *Ecosystems and Human Well-being: Scenarios*, *Vol.II,* Millennium Ecosystem Assessment (MA), Island Press, Chicago, USA, pp. 449-469.

[17] Nakicenovics et al. (2000) IPCC Special Report on Emissions Scenarios (SRES), Cambridge Press.

[18] Alcamo (2001) Scenarios as tools for international environmental assessments, Environment Issue Report No. 24, European Environment Agency.

of stabilization of CO_2 concentration, and show different costs of mitigation due to difference in the amount of required reduction. Thus CO_2 emission trajectories for stabilization are influenced by baseline scenarios.

Examples of scenarios are listed in Table 2.1.1. The future world varies depending on technological innovation and the penetration rate of such technologies. It also depends on societal change, especially the extent of renovation in social structures. Environmental burden is expected to improve under some scenarios. Some scenarios focus on global emissions and others on regional emissions and country emissions. IPCC, UNEP/GEO[19], and OECD/IEA scenarios focus on global issues. We also find many country level studies.

GHG mitigation research is likely to witness greater exploration of policy instruments for realizing CO_2 mitigation options; uncertainty in scenarios; country level scenarios and mitigation options especially for developing countries; stabilization of CO_2 for different levels of atmospheric concentration; scenarios and mitigation options for non-CO_2 GHGs and particulates; and linkages between SD and climate change objectives. Land-use change and carbon sequestration are likely to be among the other thrust areas of future development. Greater multi-disciplinary research, covering statistical, ecological and socioeconomic modeling approaches, would enhance the knowledge of dynamics of land-use change and carbon sinks, their relation to human activities and natural disturbance, and costs and benefits of mitigation options. Moreover, an increased collaboration between emissions, climate and impacts researchers is expected. This would enable more integrated assessment of mitigation and adaptation strategies and trade-offs.

Table 2.1.1 Examples of scenarios

Scenario name / Theme	Exploratory or Normative	Baseline or Policy	References
IPCC SRES scenarios 'Global GHG baseline emissions'	Exploratory	4 baseline scenario 'families': A1, A2, B1 and B2	Nakicenovic et al., 2000
IPCC Post-SRES scenarios 'Global CO2 stabilization scenarios'	Exploratory	6 types of policy scenarios based on 4 SRES scenario 'families' aiming to stabilize atmospheric CO2 concentrations by 2150	Morita et al., 2001
Millenium Ecosystem Assessment (MA) scenarios 'Global scenarios with ecosystem services'	Exploratory	4 scenarios without specific distinction between baseline and policy: Technogarden, Global Orchestration, Adaptive Mosaic, Order from Strength	Millenium Ecosystem Assessment, 2005
UNEP/GEO 'Global/regional environmental scenarios'	Exploratory	3 baseline scenarios and 1 policy scenario: Market First, Policy First, Security First, Sustainability First	UNEP/GEO3, 2002
LCS scenarios 'Regional/country scenarios with deep cuts in GHG emissions'	Normative	Policy scenarios based on regional/country perspectives	See other pages of this LCS workshop report

2.1.2 Back-casting approach

We are now facing a lot of global crises, especially in the field of environment. Several world-wise targets have been established in order to overcome them. U.N. MDG and the 60% reduction of CO_2 emission declared by UK are their example. In order to establish and to get the goals, a long-term perspective and long-term policies based on that perspective are indispensable.

In case of climate change, its impacts emerge after long years since the emission of GHG. More than 50 years is not unusual in these problems. The mitigation also requires long term

[19] UNEP (2002) Global Environment Outlook 3, UNEP-Division of Early Warning and Assessment.

efforts, especially, when the alternation of social and economic systems are needed.

Amending the society to sustainable one is also a long-term issue. It requires modifications of social and economical institutions, development of appropriate technology, and also enhancement of people's preference to such a long-term valuation. And also, we need a long years to reach such a society.

In such long-term impacts and policies, it is difficult to imagine the effects and significance with actual sensation, even if the delayed policies result in very high costs or the loosing of mitigation feasibility. Long-term viewpoint and long-term policy are quite important and essential in these cases.

Forecasting future, or extrapolation of historical and today's trends and pointing out the critical issues or estimating the future impact is the first thing to do. But, it is only the starting point. It should be followed by explicit manifestation of future target goals, deduction of required policy in order to reach there.

What is back-casting approach?

The objective of back-casting is to look for and identify the near-term actions necessary to attain long-term future goals. Usually the goals are outside of today's trend. The back-casting approach strains on, are these cases. Regardless of this out of range, in order to attain the goal, we must prepare well-laid plans, and continue considerable endeavor during a long years.

In case of realizing LCS, the fist step is to design a future LCS in (a) certain target year(s). The societies are attractive and desirable for some people, even if not for entire people, and normative in that sense that it successes to avoid future disastrous situation. Often two or more worlds are prepared which satisfy the criteria. Or in other case, no world can be described only with the present technologies and easy modification of institutions. This is the first stage of back-casting, and there remain a lot of problems to start walking toward a target society. To envisage and to enumerate alternative societies from wider point of view, in order not to regret afterward, is one thing. In case of the target world is outside of the feasible range, searching of the breakthroughs, their reality, and sacrificed opportunities in order to encompass the target world into the feasible region must be identified. This is the second stage of the back-casting.

One important thing in back-casting is to realize that the target societies are not only analytical constructs, but also social constructs. The technologies as well as the institutions of the societies should be endorsed by future people. The stack-holders of this work are distributing widely, today's generation to future generation, developed countries to developing countries, industrial sectors to residential sectors. They have their own views, stakes, capabilities, and endurances. Social interaction among these actors, especially the compassion for the future generations, can lead to learning processes not only on the cognitive level, but also with respect to values, attitudes and underlying convictions. Such "higher order learning" is the third stage of the back-casting approach. In this stage, we identify the priority of the alternative future visions, redefining and adjusting the problem definition and strategies, and what is most important, fix a tentative but robust future vision for establishing near-term policy.

Back-casting approach as a tool for transition control

Usually, introduction of one single technology or one institutional instrument is not enough to attain the future target. Combining many related technologies and institutions with organized and synergetic manner, and cooperating them toward the breaking a bundle of today's "trends" are crucial. Here, "trend" is defined as gradual change in a particular observed variable, which originates from other, possibly interrelated, and persists for a long time and covers a certain domain[20]. Trend considers only a specific domain of the society, however, the word "transition" covers a long-term, gradual continuous process of structural societal change[21]. Transitions take place through mutually reinforcing and counteracting developments in technological, economic, ecological and socio-cultural domains. Transition management is an approach designed to deliver an active contribution to the shaping of transitions, and the most important objective of back-casting is to design and analyze this transition control.

Tools for quantitative back-casting

The visions of future society may be drastically different from today's one, in terms of institution, people's preference, and industrial structure. It is difficult to design them as an extrapolation of today's system. Fundamental and basic relations governed the systems must be used to check the physical, economical, and technological feasibilities of these future societies. They are;

1) Equilibrium equations of demands and supply of people's needs
2) Balancing equations of energy, law materials, time budget, and monetary budget
3) Demand functions of people's needs
4) Production functions of goods and service based on feasible technology

These relations are handled by a group of tools called "snap-shot" models. They are;

a) Quasi steady Computable General Equilibrium (CGE) model, which concerns equilibrium of production activities and consumption activities
b) Technology bottom-up models, energy supply model, which concern engineering and economic feasibility of goods, service and energy productions
c) Household production/lifestyle model, transportation models, water management model, which concern the generation of demands

These models are used to design the target society quantitatively, checking its feasibility, and consistency.

The second group of relations is on the dynamics of the system. They are;

5) Dynamics of population and household
6) Dynamics of production capitals, social infrastructures and natural capitals
7) Cultivation, exploitation and depletion dynamics of natural capitals
8) Transition dynamics of economic institutions and instruments

They are implemented as a group of tools called "transition" models. They are;

d) Population and household model, which concerns demographic transition
e) Building dynamics model, material stock and flow model, which concern the dynamics of capital and material
f) Econometric type macro-economic model, which concerns the historical inertia of economic system

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[20] Slob, A.F.L. and Th.M.M.van Hoorn, 1999, *Major shifts in societal trends and their impact on climate change*, NRP report nr. 410200012, Bilthoven, Netherlands.

[21] Kok,M.,W.Vermeulen, A.Faaij, and D.Jager, 2002, Global warming and social innovation, The challenge of a climate-neutral society, Earthscan, 242p.

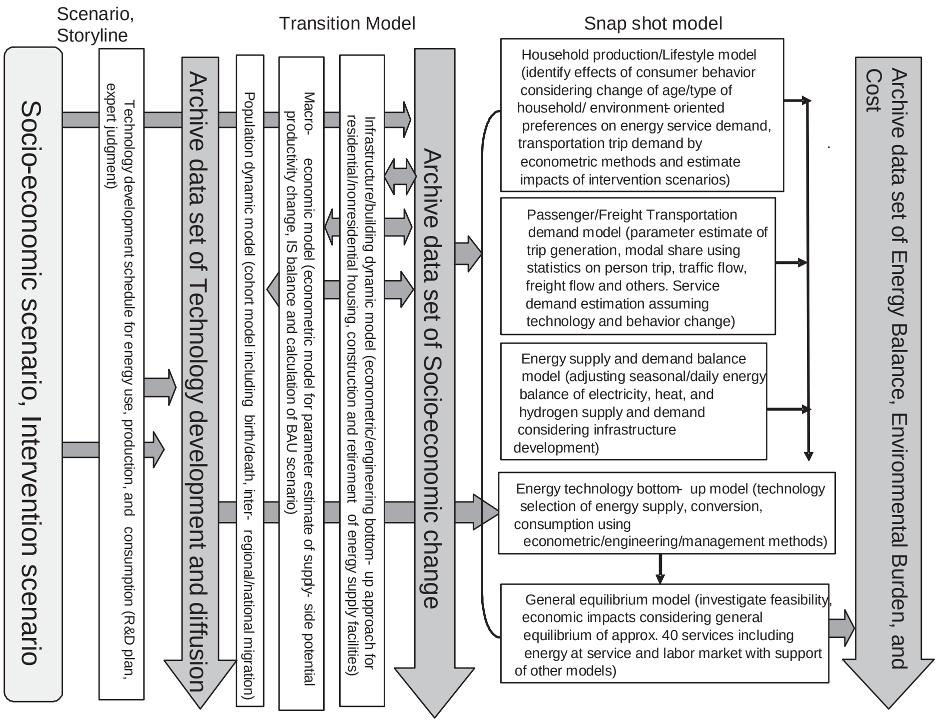


Fig. 2.1.1 Element models for Japan LCS project.

Fig. 2.1.1 shows an example of these models for Japan LCS project.

The relations described in these models should not be so aggregative, and have a certain level of mechanistic reality in order not to loose clues for trend control. Microscopic parameters used in the models should reflect historical trends; however, the future controllability should be reserved as far as possible to drive the society to target visions.

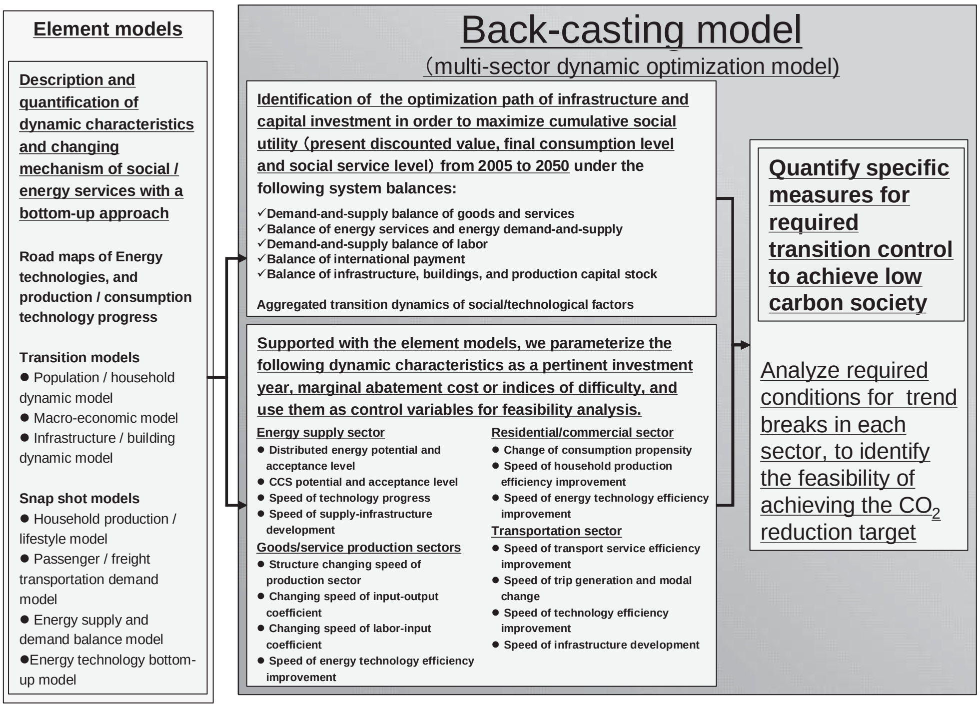


Fig. 2.1.2 Back-cast modeling frame for Japan LCS project.

Other important points are how to connect these models with consistency, and how to interact these models' information with stakeholders' recognition. Additional tool is necessary for these missions, a "back-casting model", to connect above "element" models, and to make interaction the outputs with participants, which is especially useful in the third stage of back-casting. Fig. 2.1.2 shows an example of a back-casting modeling frame for Japan LCS project. The basic principle of the frame is to write the above relations with aggregated equations, and use them as constraints of a dynamic general equilibrium scheme. In this scheme, the objective of the system is assumed to maximize a certain index, such as a time discounted social welfare and the roles of monetary balance, time balance, material balance, and demographical, economical dynamics are to identify the feasible range of future world. The model is used to find an optimum schedule of investment, necessary technology development, required cost in order to reach the target world, and what is more important, we can get quantified information between the today's effort, and the feasibility and future burdens to attain target societies.

2.2 Scenario/back-casting approaches: example from the Japan LCS project

Why do we need LCS?

One important characteristic of the climate system is its inertia. Because of past and current GHG emissions, a certain increase in global temperatures is unavoidable. Such increases in temperature carry profound risks. Even a small increase in temperatures is likely to have significant impacts on ecosystems and species, and might lead to increased drought and extreme rainfall, with severe consequences for our society. The Third Assessment Report (TAR) of the IPCC and other more recent studies has indicated the following:

i. An increase of even 1°C in the global average surface temperature compared to pre-industrial levels is likely to have a significant impact on fragile ecosystems such as coral reefs.
ii. A temperature increase between 2 and 3°C would have negative impacts globally on agriculture, water resources, and human health.
iii. A temperature above 3°C would increase the risk of significant large scale, irreversible system disruptions, such as a reversal of the land carbon sink and destabilization of the Antarctic ice sheets. Such levels are well within the range of climate change projections for the century.

The Central Environment Council (advisory committee for Ministry of the Environment, Japan) suggested that it is important to steadily collect, consider, and examine the information regarding the long-term objective to limit the temperature increase. The 2°C increase of temperature from the pre-industrial level will be good starting point for further discussion on this issue.

According to our latest model calculations, to prevent the global mean temperature from exceeding the pre-industrial level by 2℃, the global GHG reduction targets for the years 2050 and 2100 need to be about 50% and 75% of the emissions level in the 1990's, respectively (Fig. 2.2.1). For per capita emissions in 2050 to be same across the world, Japan must reduce its emissions by about 80% of the 1990 level. However these numbers include a certain amount of uncertainty arising from global warming mechanisms and climate impacts. Considering the balance of sinks and sources of GHG, a large reduction is required. This implies that the reduction rate for Japan would have to be in the range of 60-80%. Therefore, there is a need to design a LCS.

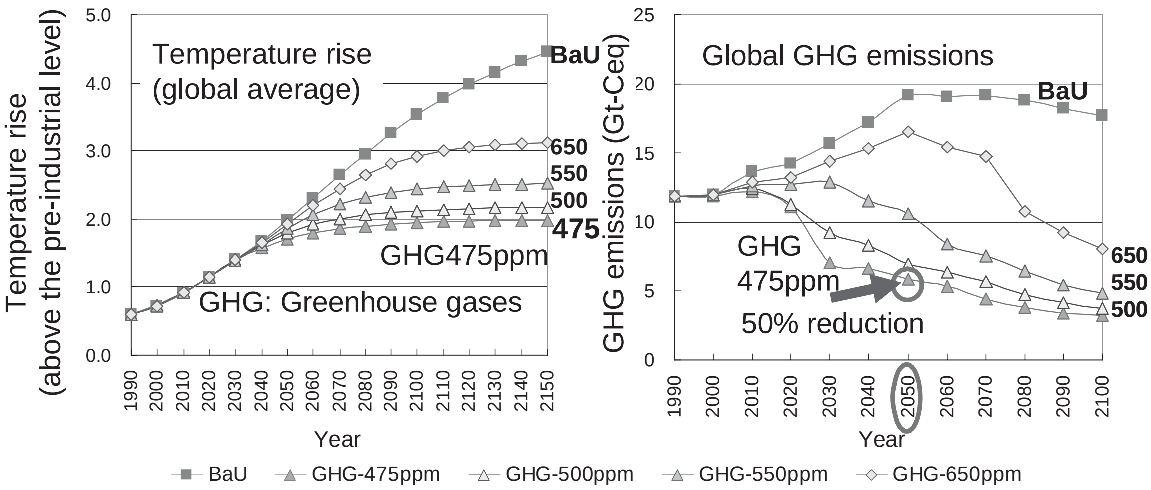


Fig. 2.2.1 Temperature rise and GHG emissions for BaU and different stabilization levels.

How to develop a LCS: Back-casting

CO_2 emissions can be disaggregated based on the following equation, which is referred to as the Kaya identity:

$CO_2 = (CO_2/E) \times (E/GDP) \times GDP$

CO_2: CO_2 emissions, E: Primary energy, GDP: Gross Domestic Production

(CO_2/E) is "carbon intensity" and improves if the share of renewables and nuclear power increases. (E/GDP) is "energy intensity" and improves if less energy is used for the same amount of GDP.

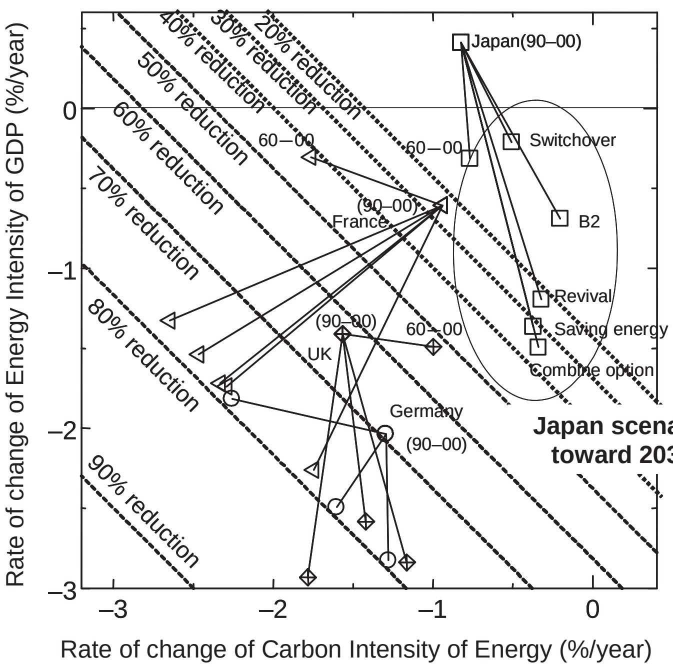


Fig. 2.2.2 Relationships between CO_2 reduction targets and rate of change of aggregated energy intensity and carbon intensity (dotted isoquant lines show the estimated CO_2 reduction over 50 years assuming annual GDP growth rate of 1% for each country; It must be noted that reduction levels shown here are not the same as those reported by each country's scenarios because they assume different GDP growth rates).

Fig. 2.2.2 shows the relationships between the CO_2 reduction targets and the rate of change in the aggregated energy intensity/carbon intensity from historical trends, and existing GHG emissions scenarios for Japan, the UK, Germany, and France. If we assume a GDP growth rate of 1% per year until 2050, CO_2 then the reduction rate will be at most 40% in 2050 based on existing future emissions scenarios in Japan. This is not enough to achieve LCS targets such as a 60-80% reduction in 2050. The results of current research on Japanese emissions scenarios indicate that a “forecasting” method, which extends current countermeasures into the future, is not likely to be suitable for developing LCS scenarios. We need ‘trend-breaking’ interventions and investments. For this reason, the back-casting method explained in section 2.1.2 is used to first develop an emissions target representing favorable LCS visions. A method for achieving it is then developed (Fig. 2.2.3).

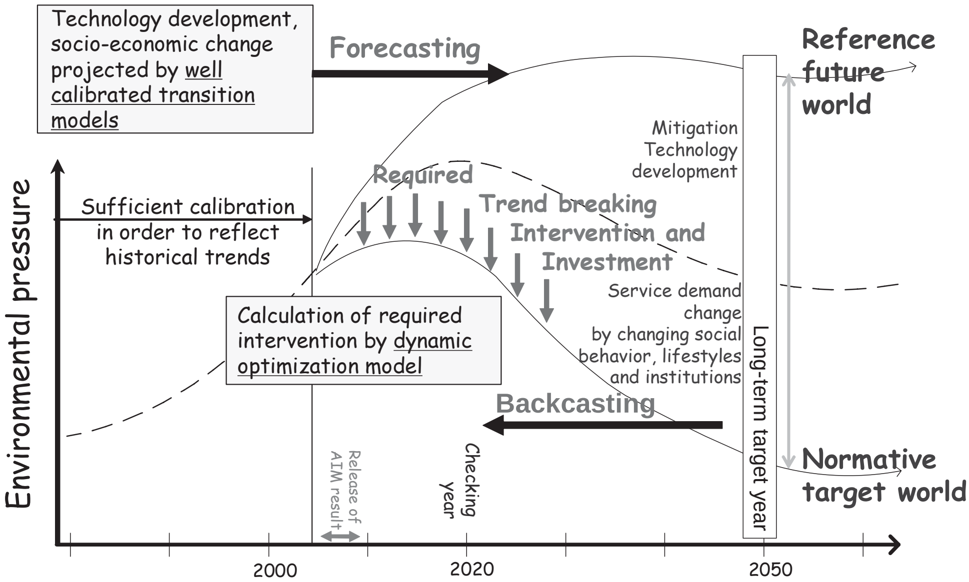


Fig. 2.2.3 Back-casting methodology for designing a LCS for Japan.

Dominant trends and two socio-economic storylines

In order to examine the feasibility of a LCS in 2050, it is important to pay attention to changes in the major social factors. One of the most obvious and drastic changes in 2050 would be the population structure. The change is mainly caused by a downturn in the birthrate over the long term. The trends of depopulation and aging are sure to continue until 2050. Continued globalization of the markets and maturation of the information society will be other major trends through 2050. The major elements can be divided into two aspects; one is strongly related to GHG emissions/LCS development, and the other dominates the Japanese development path (Fig. 2.2.4).

Along with the dominant trends mentioned above, much uncertainty exists in long-term scenarios. Although we can draw infinite pictures about our future, it is impossible to assess them all. Representing the possibilities of drastic reductions in carbon emissions is more meaningful. In order to take future uncertainties into consideration, two different scenarios were developed by focusing on cause-and-effect relationships among the factors. Summaries of the two scenarios are presented in Table 2.2.1to Table 2.2.3

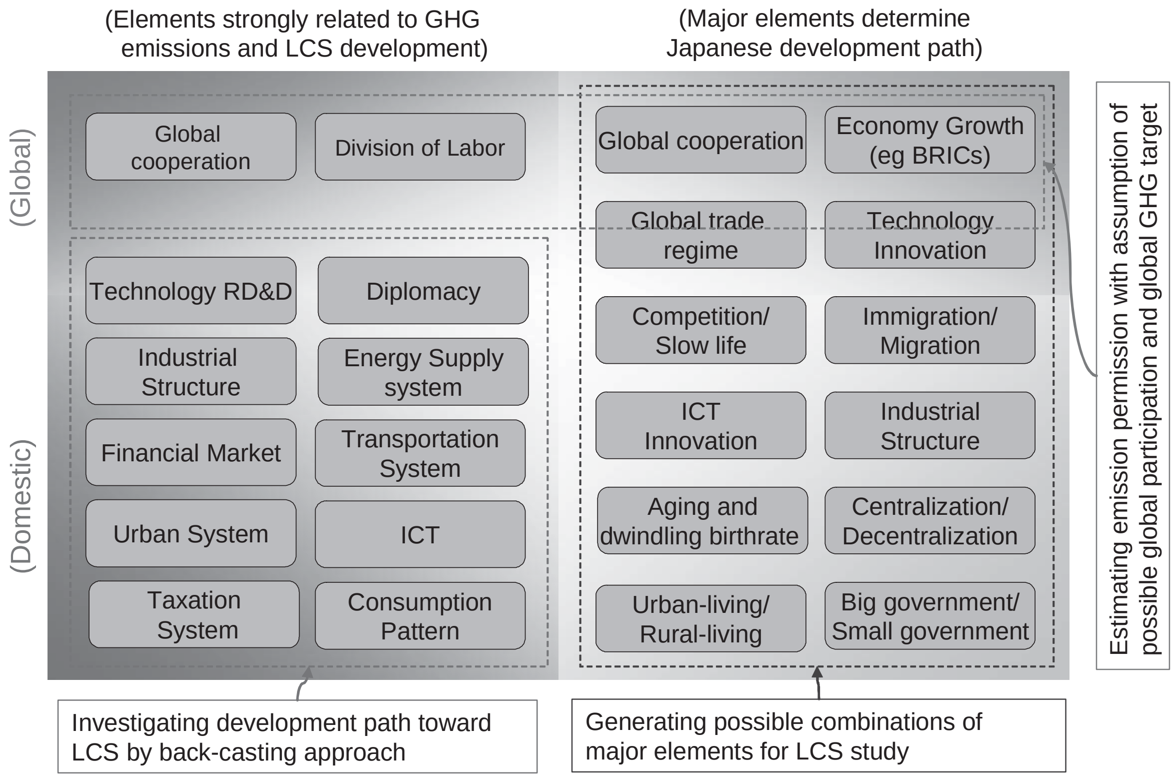


Fig. 2.2.4 Dominant elements for GHG emissions and national development for Japan.

Table 2.2.1 Two possible future Japan LCS trends toward 2050

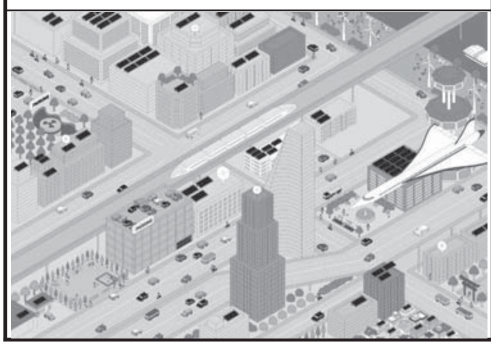
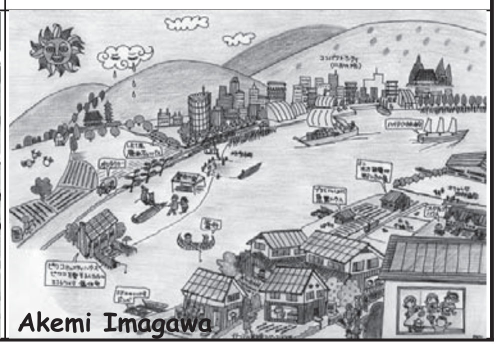
Scenario A	Scenario B
Vivid, Technology-driven	Slow, Natural-oriented
Urban/Personal	Decentralized/Community
Technology breakthrough Centralized production /recycle	Self-sufficient Produce locally, consume locally
Comfortable and Convenient	Social and Cultural Values
	

Table 2.2.2 Two possible narrative scenarios for a LCS in Japan

Scenario A Technical progresses in the industrial sectors are considerably high because of vigorous R&D investments by the government and business sectors. Economic activities as a whole are so dynamic that the average annual growth rate of the per capita GDP is maintained at 2%. Other reasons for such high economic growth are the high rates of consumption in both the business and household sectors. The employment system has changed drastically from that in 2000. Equal opportunities for employment have been achieved. Since workers are employed based on their abilities or talents regardless of their sex, nationality, or age, worker motivation is generally quite high. As many women work outside, the average time spent for housekeeping has decreased. Most household work is done by housekeeping robots or services provided by private companies. The additional time is used for personal career development. New technologies, products, and services are welcomed by society. Consumer purchasing power is strong and commodity upgrade cycles are short. The size of the household has decreased and the number of single-member households has increased. Multi-dwellings are preferred over detached houses, and the urban lifestyle is more popular than the countryside lifestyle.
Scenario B Although the average annual growth rate of the per capita GDP is approximately 1%, people can receive adequate social services no matter where they live. Volunteer work and community based mutual aid activities are the main providers of services. The levels of medical and educational service in the countryside have drastically improved, resulting in continuous migration of the population from the cities to the countryside. The number of families who own detached dwellings has increased. The trend is especially prominent in the countryside. The average size and floor area of the house have also increased. The ways people work have also changed. The practice of husbands working outside and wives working at home is no longer common. In order to avoid one partner working excessively, both partners work to secure the family’s income. Housework is shared mainly among family members, but free housekeeping services provided by local community or social activity organizations are also available. As a result of the changes in lifestyle, the family spends more time together. The time spent on hobby, sports, cultural activities, volunteer activities, agricultural work, and social activities has also increased.

Table 2.2.3 Keywords for the two LCS scenarios for Japan

Keywords		Scenario A	Scenario B
Mindset			
	Goal of life	･Social success	･Social contribution
	Residence	･Urban orientation	･Rural orientation
	Family	･Independent	･Cohabitation
	Acceptance of advanced technology	･Positive	･Prudent
Population			
	Birth rate	･Falling	･Recovering
	Acceptance of foreign workers	･Positive	･Status quo
	Emigration	･Increase	･Status quo
Landuse and cities			
	Migration	･Centralization in large cities	･Decentralization
	Urban areas	･Concentration in city centers ･Intensive land use in urban areas	･Population decrease ･Maintain minimum city functions
	Countryside	･Significant population decrease ･Advent of new businesses for efficient use of land space	･Gradual population decrease ･Local town development by local communities & citizens
Life and household			
	Work	･Increase in number of Professionals ･High-income & over-worked	･Work sharing ･Reduction & equalization of working time
	Housework	･Housekeeping robots & Services	･Cooperation with family & neighbors
	Free time	･Fee-based activities ･Career development ･Skill development	･With family ･Hobby ･Social activities (volunteer activities, etc.)
	Housing	･Multidwellings	･Detached houses
	Consumption	･Rapid replacement cycle of commodities	･Long lifetime cycle of commodities (Mottainai)
Economy			
	Growth rate	･Per capita GDP growth rate: 2%	･Per capita GDP growth rate: 1%
	Technological Development	･High	･Not as high as in scenario A
Industry			
	Market	･Deregulated	･Regulated to some degree
	Primary Industry	･Declining GDP share ･Dependent on imported products	･Recovery of GDP share ･Revival of public interest in agriculture and forestry
	Secondary Industry	･Increasing added value ･Shifting production sites to overseas	･Declining GDP share ･high-mix, low-volume production with local brands
	Tertiary industry	･Increase in GDP share ･Improved productivity	･Gradual increase in GDP share ･Increase in social activities

Innovative trend-breaks toward LCS

GHG emissions are related to various human activities. Achieving deep cuts in GHG emissions requires not only new technological developments but also changes in service demand by altering social behavior, lifestyles, and institutions.

A large part of the social infrastructure is likely to be replaced by 2050. It is possible to propose concrete policy packages including institutional changes, technology developments, and lifestyle changes that will lead to the development of a LCS.

The two scenarios presented above are pictures of possible future societies and economies envisioned from past trends and current situations. However, in order to achieve a LCS, innovative trend-breaks must be included. What would be the potential trend-break options and countermeasures in terms of reducing CO_2 emissions and energy consumption?

1) Industrial sector

Although the change in CO_2 emissions from the industrial sector has been small, it accounts for more than 40% of the national emissions. Possible countermeasures in the industrial sector include not only energy efficient technologies but also dematerialization technologies and production technologies. In addition to these technologies, changes in industrial structures and social structures (e.g., progress in informatization and the increasing relative importance of service sector changes in consumption behavior and international relations) would also have a considerable impact on CO_2 emissions from this sector.

2) Residential and Commercial sector

CO_2 emissions from the residential sector have been increasing along with the number of households and changes in lifestyles. The trend is expected to continue with the spreading use of ICT appliances and housekeeping robots.

One effective countermeasure in the residential and commercial sectors would be enhancing building insulation. The share of highly insulated residential buildings in Japan is much less than that in European countries. Approximately 60% of the heating demand from the residential sector can be cut if appropriate insulation systems are installed. It should be noted that insulation retrofitting is as important as the construction of highly insulated new houses since the proportion of new buildings constructed every year is only a small percent of the total building supply.

The development of high-efficiency appliances can also greatly reduce CO_2 emissions. Possible options would be the application of: high efficiency heat pumps (COP 6.0-8.0), high efficiency cooking appliances, fuel cells, solar photovoltaic systems, solar thermal systems, insulated bath tubs, home energy management systems (HEMS), etc.

Also crucial to achieving a LCS is promoting environmentally friendly lifestyles through school education and “eco-life navigation” systems.

3) Transportation sector

Currently, passenger and freight transportation account for approximately 16% and 10% of national final energy consumption, respectively, and a great portion of the consumption comes from motor vehicles.

Development of qualitative scenarios using LCS models

The Snapshot tool estimates CO_2 emissions in 2050 for scenarios A and B using the output from the element models shown in Fig. 2.1.1 and Fig. 3.2.1. Fig. 2.2.5 shows CO_2 emissions in 2050 by sector. 2050’s CO_2 emissions for both scenarios are 27% less than in 2000 and

30% less than in 1990, showing that both scenarios can result in a LCS by 2050.

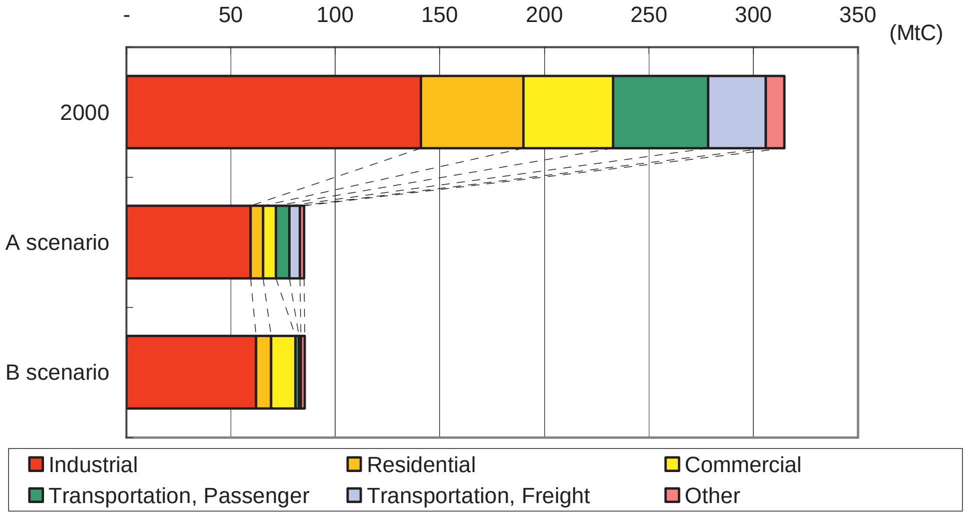


Fig. 2.2.5 CO_2 emissions by sector.

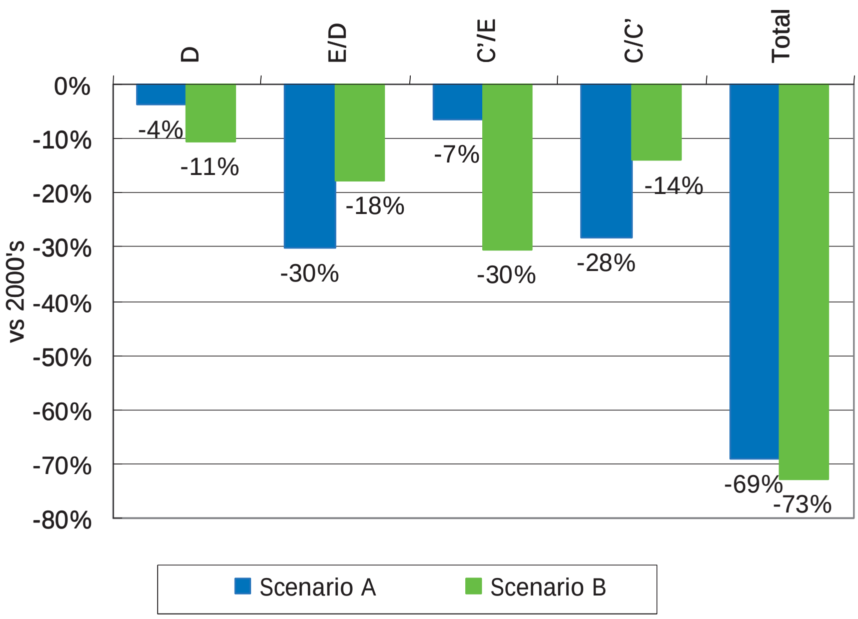


Fig. 2.2.6 Factor analysis of CO_2 emission.

Fig.2.2.6 shows a factor analysis of CO_2 emissions in 2050 and 2000. The CO_2 emissions reduction is calculated as follows:

$$\frac{\Delta C}{C} = \frac{\Delta D}{D} + \frac{\Delta (E/D)}{(E/D)} + \frac{\Delta (C'/E)}{(C'/E)} + \frac{\Delta (C/C')}{(C/C')} +$$

D: Driving Force（Service Demand)

E/D: Energy Intensity

C’/E: CO_2 Intensity in end-use sector

(not due to measures in power generation)

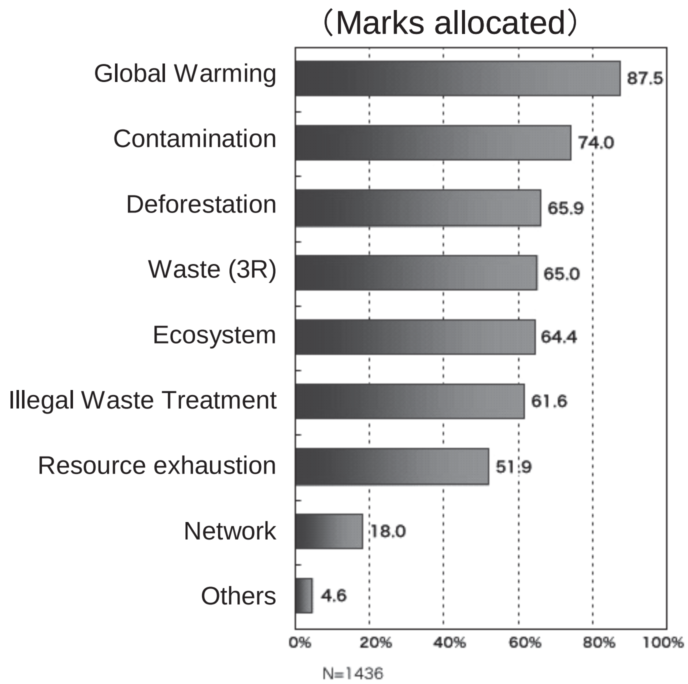
C/C’: Change in CO_2 intensity due to measures in power generation.

All of the factors help reduce CO_2 emissions in scenarios A and B, but the reduction ratios by factor differ significantly between the two scenarios. Reductions in the demand for raw materials such as steel, cement, paper, and ethylene help reduce the driving force (D) in both scenarios. Reductions in heating demand, due to the diffusion of super-insulated buildings, and transportation volume, due to more compact urban structures also help reduce D. The reduction ratio of the driving force is larger in scenario B than in A due to lower economic growth. Energy efficient technologies help reduce the energy intensity (E/D) in both scenarios. The reduction rate of E/D is larger in scenario A due to the diffusion of advanced technologies such as efficient heat pumps, electric vehicles, and fuel-cell vehicles. The increased use of electricity and the diffusion of photovoltaic systems help reduce the carbon intensity in the end-use sector (C'/E) in both scenarios. The reduction rate of C'/E is larger in scenario B due to the large amount of biomass consumption; it is equivalent in volume to oil and gas consumption. Efficient steam power plants help reduce the carbon intensity in the power generation sector in both scenarios. The reduction of C/C' is larger in scenario A due to the maintained share for nuclear power and the introduction of carbon capture and storage (CCS).

Aligning a LCS and SD in Japan

Though a public opinion survey shows that the environmental problem of greatest concern in Japan is global warming, we also worry about other issues such as contamination, deforestation, recycling, and the ecosystem. It is necessary to consider the relationships among the main environmental issues and find win-win options for SD. By improving forest management, more carbon-free materials and bioenergy will be available and the value of the ecosystem will be enhanced.

As one of the top economies and technological countries in the Asia-Pacific region, Japan faces new economic, social and environmental problems. If Japan can show possible and favorable solutions for aligning a LCS and SD, both Japan and the other Asian countries will benefit.



http://www.nikkeibp.co.jp/style/biz/enquete/051021quick_eco/

Fig. 2.2.7 Survey of citizens on environmental concerns.

3 Innovative trend-breaks toward LCS and SD

Chapter 2 described the basic concepts of the scenario approach and the back-casting approach and discussed a case study of the Japan LCS scenarios. These scenarios are visions of a future society and economy based on past trends and current situations. However, in order to achieve the goals of a LCS and SD, innovative trend-breaks must be included. What are the potential trend-break options and countermeasures for reducing CO_2 emissions and contributing to SD?

3.1 Trend-breaking options

The effects and feasibilities of the trend-breaking options are heavily dependent on social conditions. This chapter discusses combinations of options for specific scenarios.

In one scenario based on high technological development of the society, the advent and maturation of advanced technologies such as fuel cells, electric vehicles, next-generation nuclear power, CCS (Carbon Capture Storage), and other energy efficient technologies would be the main options for achieving a LCS. Since such a scenario has relatively high economic growth, the pace of technology advancement could compensate for the increased driving forces associated with economic growth, thereby reducing CO_2 emissions.

In another scenario based on relatively low economic growth and a decrease in the population, energy demand would fall but technological developments would likely have no effect. In such a scenario, it is assumed that the public will hesitate to accept nuclear power and CCS, while fuel cells and electric/hydrogen vehicle technologies will be too immature to become established in the market. Alternatively, changes in lifestyles through appropriate education would be a major measure towards achieving a LCS. In addition, renewable energy technologies such as solar photovoltaic, biomass fuel, and wind should be exploited as much as possible.

With regard to achieving the goals of SD, the target issues are much more complicated than those of a LCS, with various factors cross-cutting each other. However, the options for a LCS also benefit SD in many cases. For example, if the options in the industry, transportation, and power generation sectors become more efficient, not only will energy demands and CO_2 emissions be reduced, thereby promoting a LCS, but air pollutant emissions will also be reduced, thereby promoting SD. Moreover, air quality will be improved. Table 3.1.1 shows examples of trend-breaking options.

Table 3.1.1 Example trend-breaking options

Sector	Options
Industry	▪Energy-efficient production technology ▪Efficient production technology for reducing raw materials
Residential and Commercial	▪Insulation of buildings ▪Diffusion of all-electric homes ▪Diffusion of high efficiency heat pump air conditioners and water heaters ▪Development and diffusion of fuel cells ▪Optimal energy control using HEMS ▪Installation of photovoltaic systems (especially in detached houses) ▪Use of biomass fuels for cooling ▪Diffusion of solar water heating ▪Education (Eco life navigation system)
Transportation	▪Shortening trip distances for commuting through intensive land use ▪Modal shift from cars to mass transit systems (buses, railways, light-rail transit systems) ▪Diffusion of electric vehicles, fuel cell vehicles, etc. ▪Urban structures become more compact ▪Infrastructure development for pedestrians and bicycle riders (sidewalk, bikeway, cycle parking) ▪Diffusion of biomass hybrid cars ▪Modal shift from cars to railways, and to ships for freight transportation
Energy supply	▪Expansion of nuclear power generation ▪Electric load levelling and expansion of electric storage (eg., store electricity generated at night and use it for electric vehicles ▪High efficiency fossil fuel technologies + CCS ▪Hydrogen production from fossil fuels + CCS ▪Infrastructure development for hydrogen production, transportation, storage, application ▪Increased use of renewable energy (wind, photovoltaic, solar thermal, biomass) ▪Application of information technologies for adjusting loads
Supply and waste management	▪Use of fewer materials during production through technology development ▪Further development of recycling technologies ▪Longer service life for goods ▪Lower consumer demand due to changes in personal/social values ▪ Consumer preference for recycled products
Water management	▪Lifestyle changes to save water ▪Diffusion of water-saving technologies, such as ultra-low water-volume flush toilets, ecological sanitation ▪Diffusion of water reuse systems

3.2 Tools for developing coherent future visions

In order to evaluate the feasibility and social impacts of the trend-breaking options described above, the driving forces associated with social changes in each sector need to be simulated. In the simulation, the characteristics and constraint conditions of each sector should be taken into account. It is also important to ensure consistency among the sectors.

In the AIM model family, the goals of a LCS and SD are handled by developing several element models that ensure consistency in the envisioned future society. Figure 3.2.1 and Table 3.2.1 illustrate the relationships between the items that need to be taken into account in each sector and the element models. Detailed descriptions of each model are given in Chapters 4 and 5.

Table 3.2.1 Items to be considered in each sector and related models

	Items to be considered	Developed Models
Industry	a. Changes in industrial structure, technological developments in energy consumption and productivity	▪Inter-sector and macroeconomic Model[22] ▪Enduse model ▪Enduse (Air) model
Domestic and Commercial	b. Changes in building distribution by climatic zone c. Changes in the shares of detached homes and multidwellings d. Diffusion rate of insulated detached homes and multidwellings e. Changes in service life of dwellings f. Lifestyle changes in household consumption and allocation of time	▪Building Dynamics model (b-e) ▪Enduse model (b-e) ▪ Household Production and Lifestyle model (f)
Transportation	g. Changes in population distribution and local characteristics h. Changes in social environment and human activities i. Changes in selectivity of the mode of passenger transportation by area j. Changes in industrial structure k. Dematerialization l. Changes in production/consumption area m. Changes in selectivity of the mode of transportation by distance	▪ Transportation Demand model (g-m) ▪Enduse model (g-m) ▪Enduse (Air) model (g-m)
Energy supply	n. Function of load management, uncertainties in both energy supply and demand o. Combination of small consumer and small energy sources + electricity/hydrogen p. Feasibility of local production for local consumption	▪ Energy Supply model (n-p) ▪Enduse (Air) model (n-p)
Social system	q. Relationship between economic activities and supply/flow of the materials r. Amount of waste derived from the stock s. Effectiveness of recycling and its impacts	▪ Material Supply and Flow model (q-s)
Water management	t. Changes in safe water and sanitation coverage by technology u. Changes in water management efficiency v. Changes in investment costs for safe water and sanitation infrastructure	▪ Water Management model (t-v)
Cross sectional	w. Ensuring consistency among the sectors in terms of energy demand and supply x. Impacts of future technological choices on social energy efficiency y. Ensuring economical consistency of LCS	▪ Energy Snapshot Tool (w) ▪ SDB (x) ▪ Inter-sector and macroeconomic Model(y)

[22] Inter-sector and Macro Economic Model (IMEM) consists of a static general equilibrium module (CGE model) for a single country and a macroeconomic module. In this booklet, as a part of IMEM model, only CGE module is explained in detail (See Chapter 5.1.1)

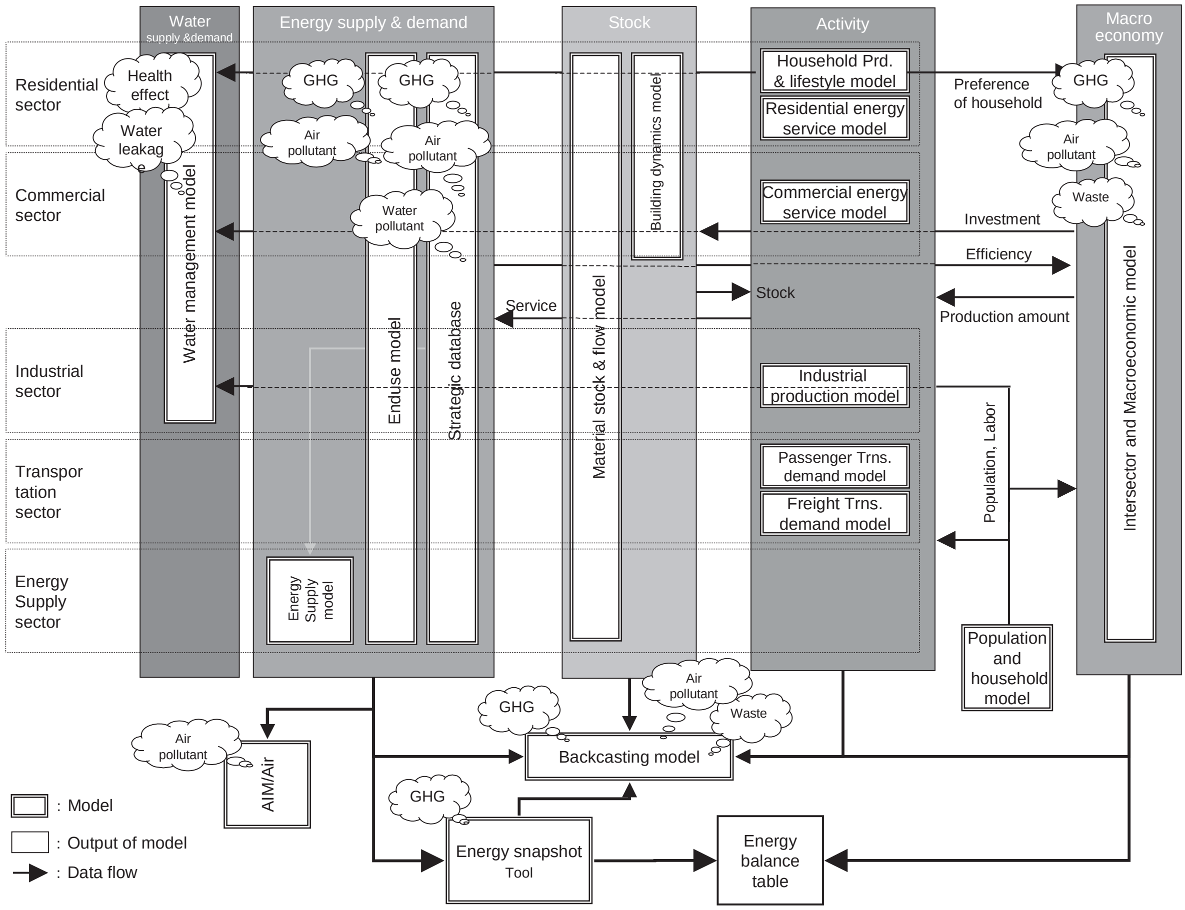


Fig. 3.2.1 Relationship among element models for LCS and SD.

4 Core model

4.1 Strategic DataBase (SDB)

4.1.1 Characteristics of SDB

SDB is a database system that stores information of activities which accompany or reduce environmental burden. Activity includes energy technology, institution, infrastructure, lifestyle and so on. As shown in
Fig. 4.1.1, narrative description and quantitative value are entered in the form. All the items in the activity form is shown in Table 4.1.1.

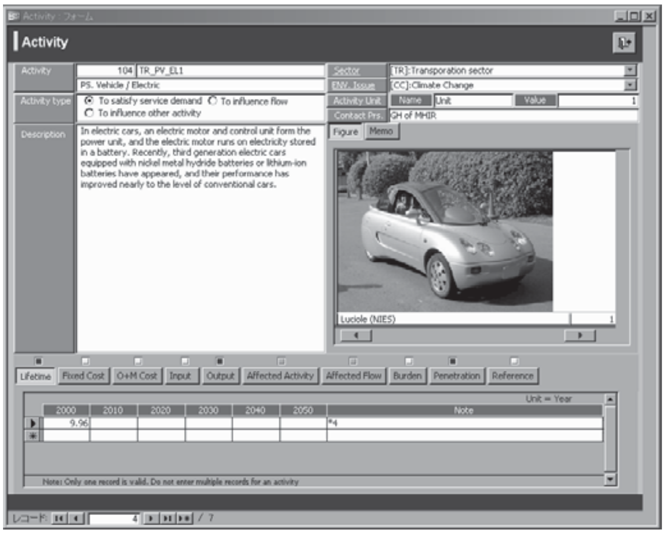


Fig. 4.1.1 Form of activity in EDB.

Table 4.1.1 Item of activity

Item	Content
Activity type	Type of the activity
Description	Description of the activity
Sector	Sector activity belongs
Activity unit	Unit of activity amount
Figure	Picture or illustration of the activity
Memo	Data source, estimation method, reference etc.
Lifetime	Lifetime
Fixed cost	Fixed cost per activity
O&M cost	Operating and maintenance (O&M) cost per activity. O&M cost here does not include the cost which accompanies inputs
Input	Input per activity
Output	Output per activity
Affected activity	(This item is available when the activity type is "Activity to influence other activity") Increase(+)/decrease(-) rate of affected item of other activity
Affected flow	(This item is available when the activity type is "Activity to influence flow") Increase(+)/decrease(-) rate / quantity of affected flow
Environmental load	Time-wise value of environmental burden emission per activity. The emission includes the direct emission, not include the emission with input
Penetration	Penetration rate of the activity
Reference	Reference

4.1.2 Application to Japan

The members of LCS 2050 project (LCS2050) provide the information of the activities. The database plays as the information exchange platform of teams of LCS2050. The estimating module in the SDB calculates future projections under the scenarios of alternative policy. If the share of the activity among the alternative / competitive ones can be estimated with cost minimization, the Bottom-up engineering model is used. ESS (Energy Snapshot tool) and CGE model use energy improvement and countermeasure cost from the simulation output of SDB and/or Bottom-up engineering model.

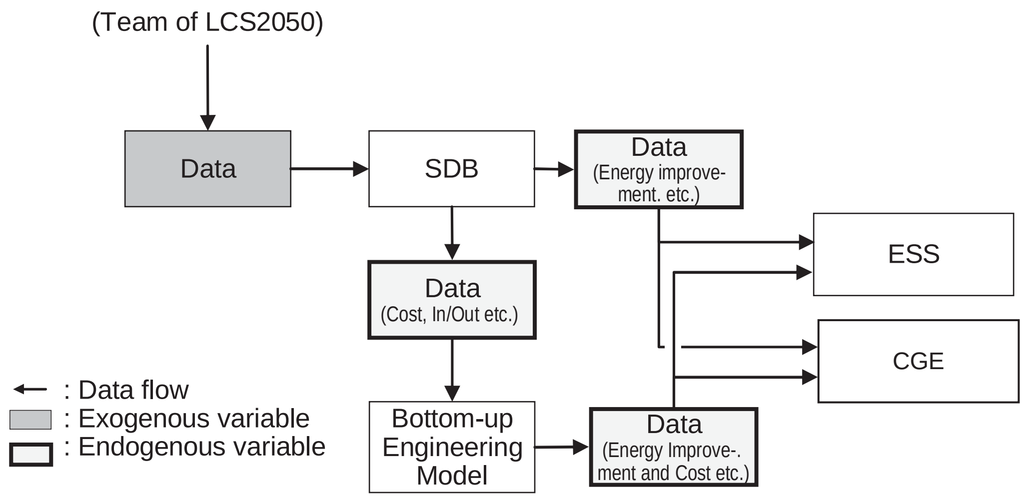


Fig. 4.1.2 Data linkage of models via SDB.

4.2 Bottom-up/accounting model 1: AIM/Energy SnapShot tool (ESS)

4.2.1 Characteristics of ESS

The Energy SnapShot tool (ESS) is developed on the spreadsheet as shown in Fig. 4.2.. Giving service demand, share of energy and energy improvement by classification of service and energy in the base year and the target year, the tool calculates the energy balance table and the CO_2 emission table immediately with keeping consistency among sectors.

Since users can conduct sensitivity analysis with different parameters promptly, the tool is suitable for the communication among stakeholders to design LCS. Besides, the tool can be used as a simple assessment tool of output from various models.

Residential sector

1 Energy service demand

	Unit	2000	2050					
			REF		CM		CM/REF	
			A	B	A	B	A	B
Cool	Mtoe	3	5	3	4	3	90%	90%
Warm	Mtoe	17	15	13	10	9	67%	67%
Hot Water	Mtoe	11	7	12	6	9	80%	80%
Cooking (S)	Mtoe	1	1	1	1	1	100%	100%
Cooking (E)	Mtoe	1	1	1	1	1	100%	100%
Lighting	Mtoe	3	5	3	4	3	80%	80%
Refrigerator	Mtoe	4	3	3	3	3	100%	100%
ICT	Mtoe	2	3	2	3	2	100%	100%
Appliance	Mtoe	10	13	10	13	10	100%	100%
					0	0		
					0	0		

REF = Reference case
CM = Countermeasure case

4-6 Energy consumption / CO2 Emission

		Unit	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
4 Energy Consumption	2000	Mtoe	0	21	9	0	1	0	0	23	54
	2050 A (CM)		0	1	1	0	8	0	4	14	28
	2050 B (CM)		0	2	2	7	18	0	0	8	37
5 Emission Factor	2000	MtC/Mtoe	1.05	0.80	0.55	0.00	0.00	0.00	0.00	1.19	-
	2050 A (CM)		1.05	0.80	0.55	0.00	0.00	0.00	0.52	0.28	-
	2050 B (CM)		1.05	0.80	0.55	0.00	0.00	0.00	0.00	0.63	-
6 CO2 Emission	2000	MtC	0	16	5	0	0	0	0	27	49
	2050 A (CM)		0	1	0	0	0	0	2	4	7
	2050 B (CM)		0	1	1	0	0	0	0	5	7

2 Service Share

	Unit	2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Warm	-	0%	59%	15%	0%	0%	0%	0%	26%	100%
Hot Water	-	0%	55%	33%	0%	7%	0%	0%	5%	100%
Cooking (S)	-	0%	44%	56%	0%	0%	0%	0%	0%	100%
Cooking (E)	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Lighting	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Refrigerator	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
ICT	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Appliance	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%

	2050 A (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								100%	100%
Warm		5%	5%			10%		80%	100%
Hot Water		5%	5%		10%	10%		70%	100%
Cooking (S)		5%	5%					90%	100%
Cooking (E)								100%	100%
Lighting								100%	100%
Refrigerator								100%	100%
ICT								100%	100%
Appliance								100%	100%
									0%
									0%

	2050 B (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								100%	100%
Warm		5%	5%	50%				40%	100%
Hot Water		10%	10%	20%	30%			30%	100%
Cooking (S)		15%	20%	35%				30%	100%
Cooking (E)								100%	100%
Lighting								100%	100%
Refrigerator								100%	100%
ICT								100%	100%
Appliance								100%	100%
									0%
									0%

3 Energy efficiency

	Unit	2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	toe/toe								2.84	-
Warm	toe/toe		0.90	0.90	0.90				3.69	-
Hot Water	toe/toe		0.75	0.75	0.75	1.00			0.62	-
Cooking (S)	toe/toe		0.45	0.45	0.45	0.45			0.70	-
Cooking (E)	toe/toe								1.00	-
Lighting	toe/toe								1.00	-
Refrigerator	toe/toe								1.00	-
ICT	toe/toe								1.00	-
Appliance	toe/toe								1.00	-
										-
										-

	2050 A (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								8.00	-
Warm		0.90	0.90	0.90		1.00		8.00	-
Hot Water		0.95	0.95	0.95	0.95	1.00		6.00	-
Cooking (S)		0.55	0.55	0.55	0.55			0.80	-
Cooking (E)								1.11	-
Lighting								1.50	-
Refrigerator								1.50	-
ICT								2.00	-
Appliance								1.50	-
									-
									-

	2050 B (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								8.00	-
Warm		0.90	0.90	0.90		1.00		8.00	-
Hot Water		0.95	0.95	0.95	0.95	1.00		6.00	-
Cooking (S)		0.55	0.55	0.55	0.55		0.55	0.80	-
Cooking (E)								1.11	-
Lighting								1.50	-
Refrigerator								1.50	-
ICT								2.00	-
Appliance								1.50	-
									-
									-

Fig.4.2.1 ESS (partly, Residential sector)

4.2.2 Structure of ESS

Figure 4.2.2 shows the flow of estimating energy balance table and CO_2 emission table. The tool calculates energy consumption of the end-use sectors, e.g. industrial, residential, commercial and transportation sector, by energy classification and service classification with using service demand, mixture of energy and energy improvement given exogenously. Then it calculates energy consumption power generation with electricity demand in the end-use sector. Energy balance table is created with the energy consumption in end-use sector and power generation sector. Finally CO_2 emission table is created with CO_2 emission factor given exogenously.

Sector, service, energy as indices of Japan's ESS includes the elements show in Table 4.2.1.

Table 4.2.1 Indices of Japan's ESS

Indices	Classification	Elements
Sector	19	Industrial, Residential, Commercial, Transportation
Service	32	Industrial : Crude steel production, Cement production, Ethylene production, Paper production, other production by industrial category
		Residential : Warming, Cooling, Hot water, Cooking, Lighting, ICT, Other services
		Commercial : Warming, Cooling, Hot water, Cooking, Lighting, Motor others
		Transportation, Passenger: Cars(Mini/Small/Medium), Buses, Railways, Maritime, Aviation
		Transportation, Freight : Cars(Mini/Small/Medium), Railways, Maritime, Aviation
		Power generation
Energy	10	Coal, Oil, Gas, Biomass, Hydro, Nuclear, Solar/Wind, Hydrogen, Heat, Electricity

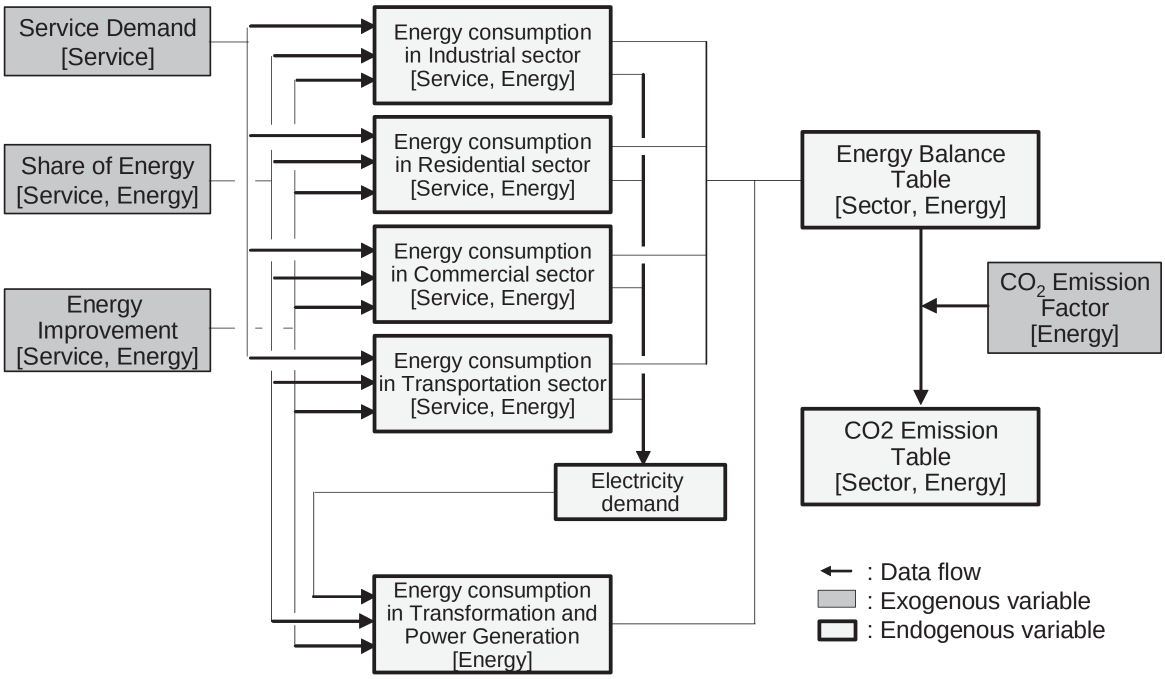


Fig. 4.2.2 Flow chart for ESS.

4.2.3 Application to Japan

See Chapter 2.2..

4.3 Bottom-up/accounting model 2: AIM/Enduse Model

4.3.1 Characteristics of AIM/Enduse Model

AIM/Enduse Model is a bottom-up model of technology selection within a country's energy-economy-environment system. Technologies are selected in a linear optimization framework in which system costs are minimized by several constraints such as service demands and the availability of energy and materials. System costs include fixed costs, the operating costs of technologies, energy costs, taxes and subsidies, etc. The AIM/Enduse Model can simultaneously calculate the costs for multiple years. It can also analyze various scenarios, including policy countermeasures.

4.3.2 Structure of AIM/Enduse Mode

Fig.4.3.1 shows the structure of the AIM/Enduse Model. "Energy technology" refers to a device that provides a useful service by consuming energy. "Energy service" refers to a measurable need that must be satisfied. For example, in the residential sector, the air conditioner is an energy technology and space cooling is an energy service. In the transportation sector, a vehicle is an energy technology and the transportation of people is an energy service. The unit of energy service varies with the type of service.

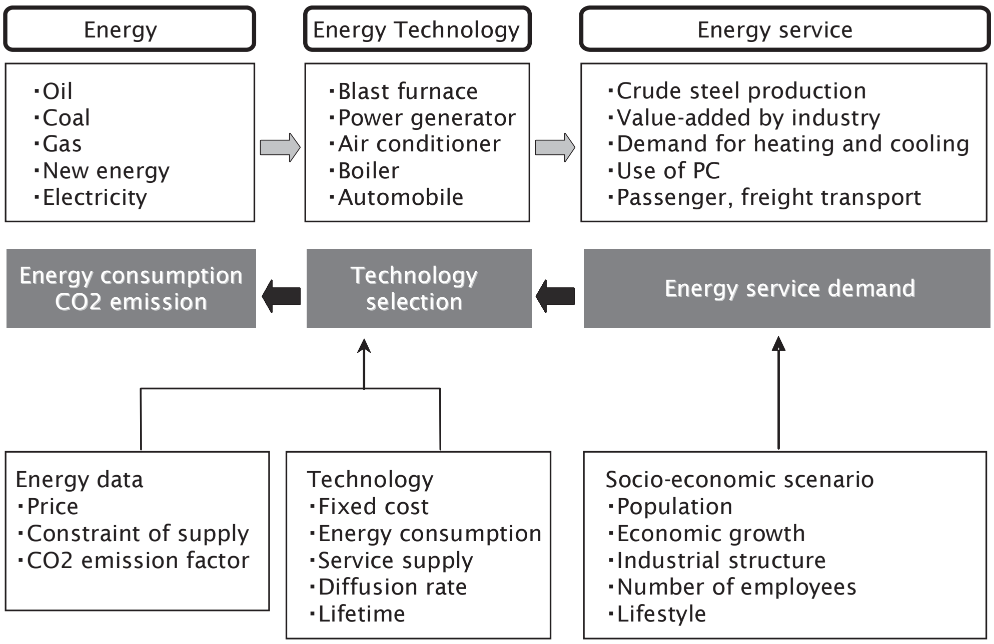


Fig. 4.3.1 Structure of AIM/Enduse Model.

a) Estimating energy demand and CO_2 emission

The energy-service demands used in this model are based on scenarios or results obtained from other models. The combination of technologies is then endogenously calculated according to the logic shown below in order to satisfy service demands. Next, the energy consumption is calculated from the specific energy consumption of each technology and the combination of technologies. Finally, the CO_2 emissions are calculated from the energy consumption and emission factors for each energy type.

b) Logic of technology selection

The AIM/Enduse Model creates combinations of energy technologies in order to minimize the total annual cost of supplying energy services under several constraints, such as the availability of energy and the maximum share of technology diffusion. The payback time method expresses the total annual cost. In Fig. 4.3.2, the payback period is three years.

Three types of cohort changes are taken into account simultaneously in the AIM/Enduse Model: 1) recruitment of a new technology at the end of the service life of an older technology or when energy service demand increases; 2) improvement of an existing technology; and 3) replacement of an existing technology, even though the existing technology remains in service. In the first case, the least costly technology in terms of the initial cost and the 3-year running cost, including energy and maintenance costs, is selected. In the second case, improvements are adopted by comparing the total cost (the necessary improvement cost and the running cost for 3 years after the improvement) and the 3-year running cost before improvement. In the third case, the 3-year running cost of the working technology is compared with the total cost (the initial cost and the 3-year running cost of the new related technology). In the third case, a new energy-saving technology should be selected only when the initial cost of the technology is less than the difference in the running costs for the old and new technologies for the duration of the payback period. Thus, it is more difficult to select an energy-saving technology in the third case than in the first case.

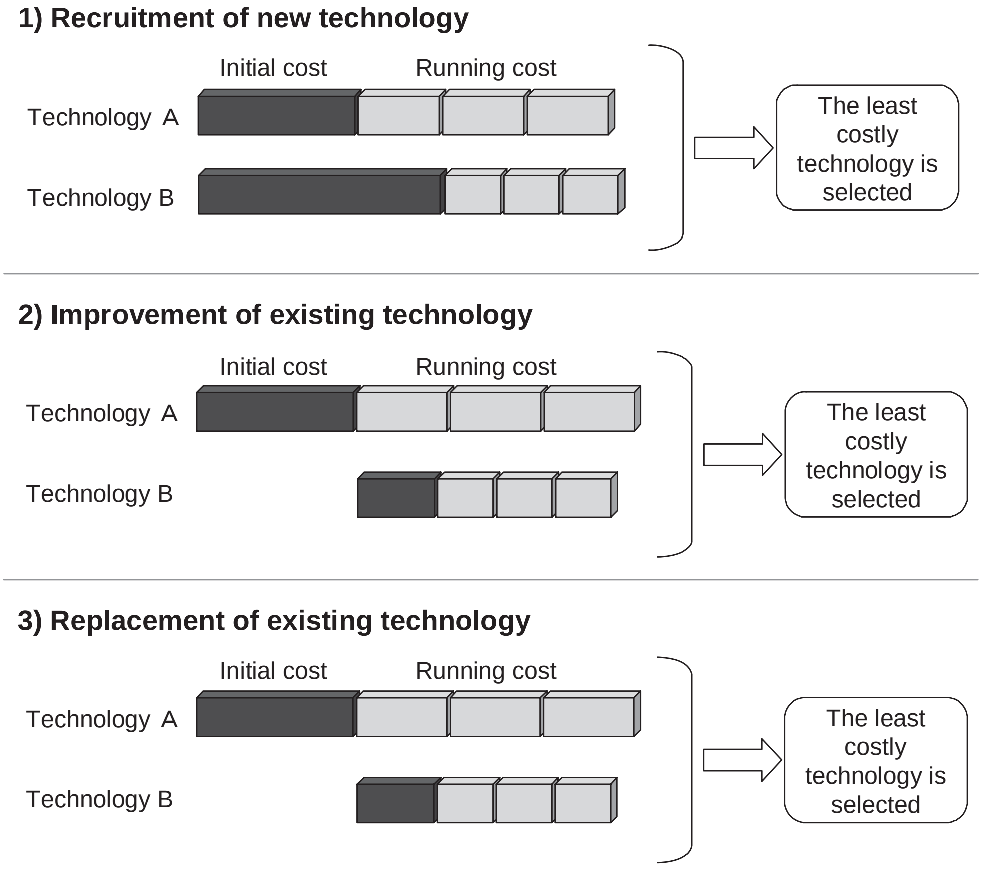


Fig. 4.3.2 Logic of technology selection.

4.3.3 Application to Japan

Fig. 4.3.3 shows results of a simulation of a carbon tax policy in Japan. When new energy-saving technologies do not spread in the future, CO_2 emissions will steadily increase (line A). When energy-saving technology improvements are selected based on their cost (least costly), then CO_2 emissions follow the course indicated by line B. When a carbon tax is imposed, CO_2 emissions fall according to the carbon tax rates (lines C and D). When tax revenues are used to subsidize CO_2 emissions reductions, then emissions will follow the course indicated by line E. By using tax revenues to subsidize the diffusion of technologies and applying a relatively low carbon tax rate, CO_2 emissions can be substantially reduced (Table 4.3.1).

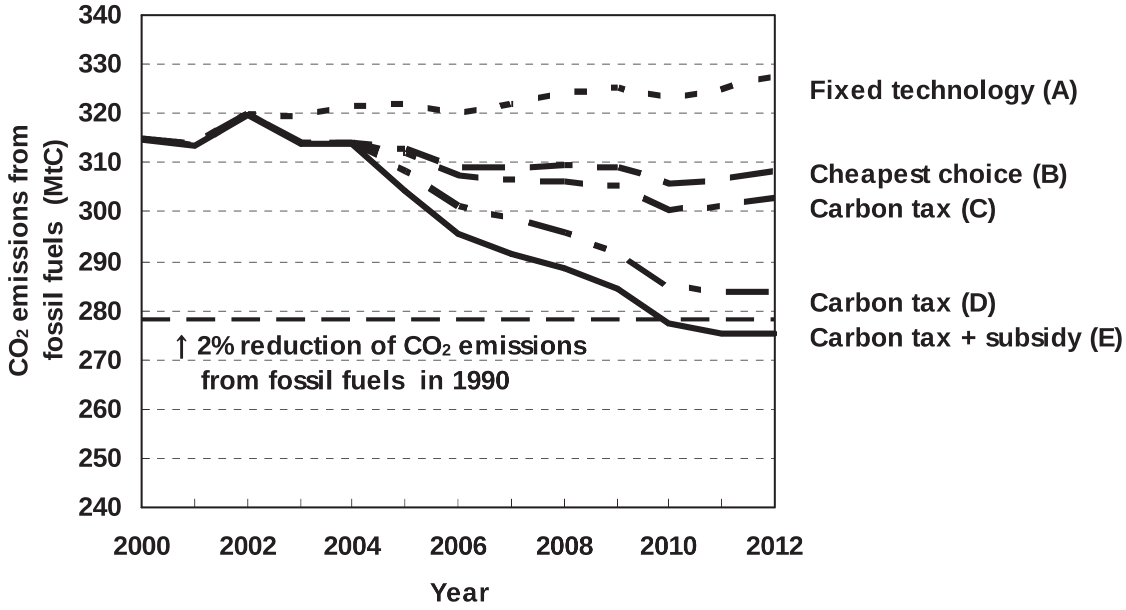


Fig. 4.3.3 Results of simulation of CO_2 emissions.

Table 4.3.1 Subsidies coupled with carbon taxation

Sector	Subsidized measures and devices
Industrial sector	Boiler conversion control, high-performance motors, high-performance industrial furnaces, waste plastic injection blast furnaces, LDF with closed LDG recovery, high-efficiency continuous annealing, diffuser bleaching devices, high-efficiency clinker coolers, biomass power generation
Residential sector	High-efficiency air conditioners, high-efficiency gas stoves, solar water heaters, high-efficiency gas cooking devices, high-efficiency televisions, high-efficiency VCRs, latent heat recovery type water heaters, high-efficiency illuminators, high-efficiency refrigerators, standby electricity savings, insulation
Commercial sector	High-efficiency electric refrigerators, high-efficiency air conditioners, high-efficiency gas absorption heat pumps, high-efficiency gas boilers, latent heat recovery type boilers, solar water heaters, high-efficiency gas cooking devices, high-frequency inverter lights with timers, high-efficiency vending machines, amorphous transformers, standby electricity saving, ventilation with heat exchangers, insulation
Transportation sector	High-efficiency personal gasoline cars, high-efficiency diesel cars, hybrid taxis, high-efficiency diesel buses, high-efficiency small-sized trucks, high-efficiency standard-sized trucks
Forest management	Plantations, weeding, tree thinning, multilayered thinning, improvement of natural forests

4.4 AIM/Back-casting model (BCM)

4.4.1 Characteristics of BCM

This model represents the intertemporal optimal strategy for introducing new technologies and economic activity changes in order to achieve future targets, such as carbon emissions in 2050. The core model is a dynamic optimization model with a linear program. Countermeasures proposed by other models can be introduced and evaluated.

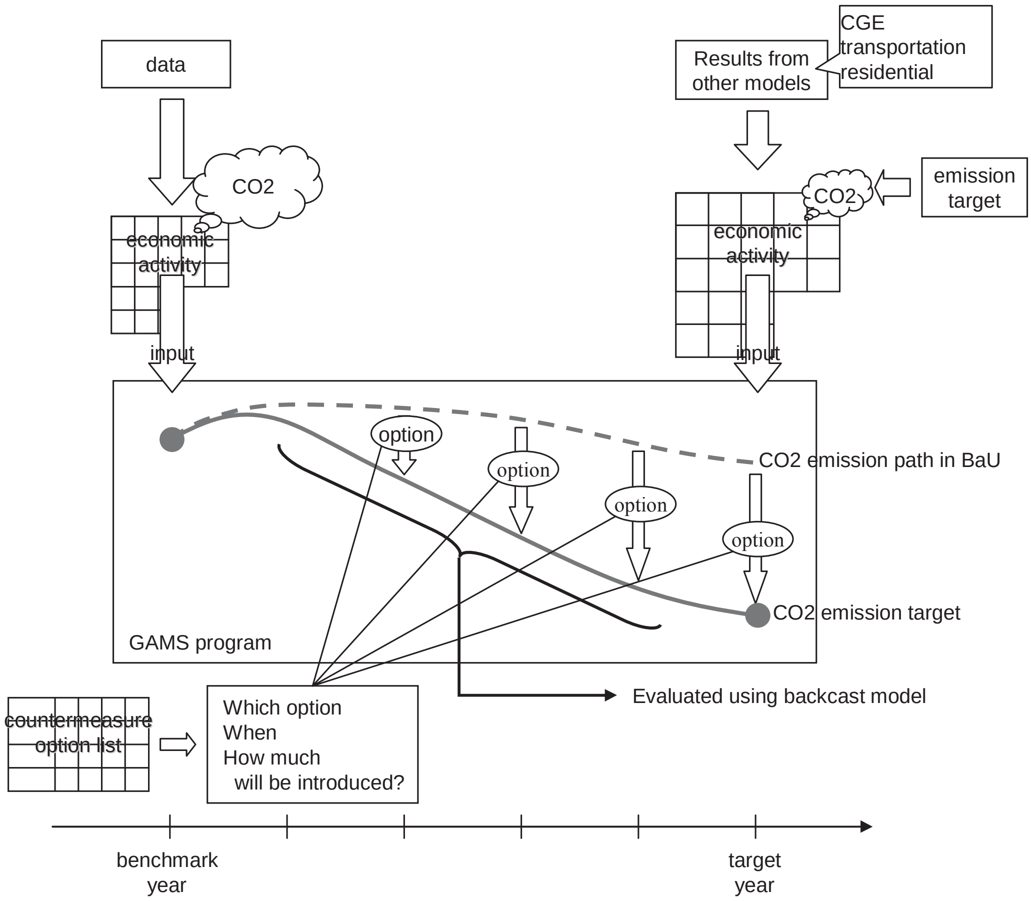


Fig. 4.4.1 Concept of BCM.

4.4.2 Structure of BCM

This model has following features.

- Production function: mechanism of processes for goods and services production
- Supply-demand balances of all goods and services
- Supply dynamics equation
- Recycling of materials
- Population dynamics
- Balance of time use: allocation of 24 hours to working hours, free time, etc.
- Trade conditions: imports and exports
- Minimum service requirement
- Constraint on carbon emissions
- Social welfare derived from final consumption and installed supply: objective function of this model

The following parameters are handled outside this model.

- Parameters for production functions and their modification: aggregation of results estimated from related bottom-up models, and future scenarios.
- Parameters for supply dynamics equation, population dynamics equation, balance of time use and trade function (based on historical data and future scenarios)
- Input of minimum service requirement
- Parameters for materials recycling

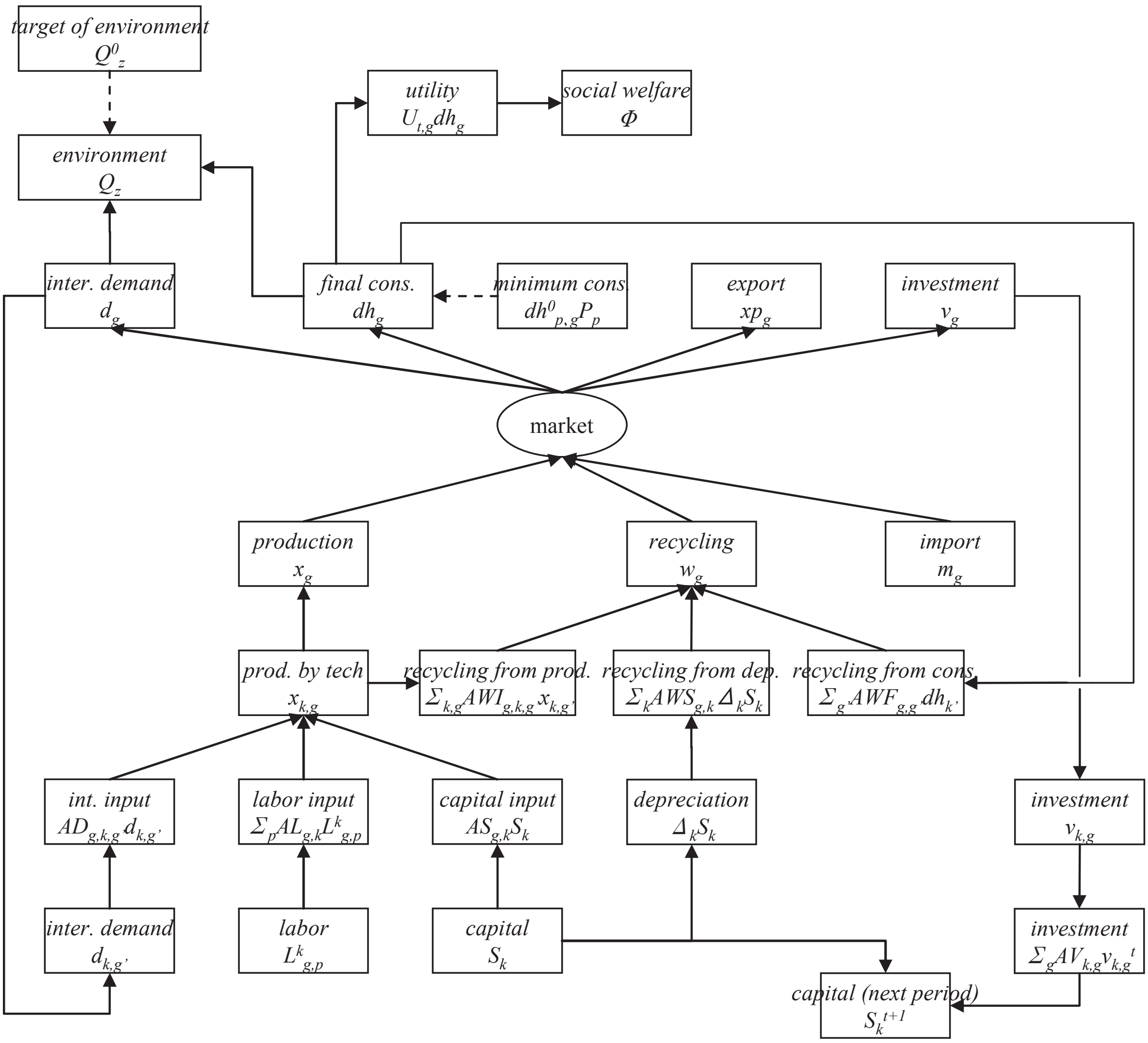


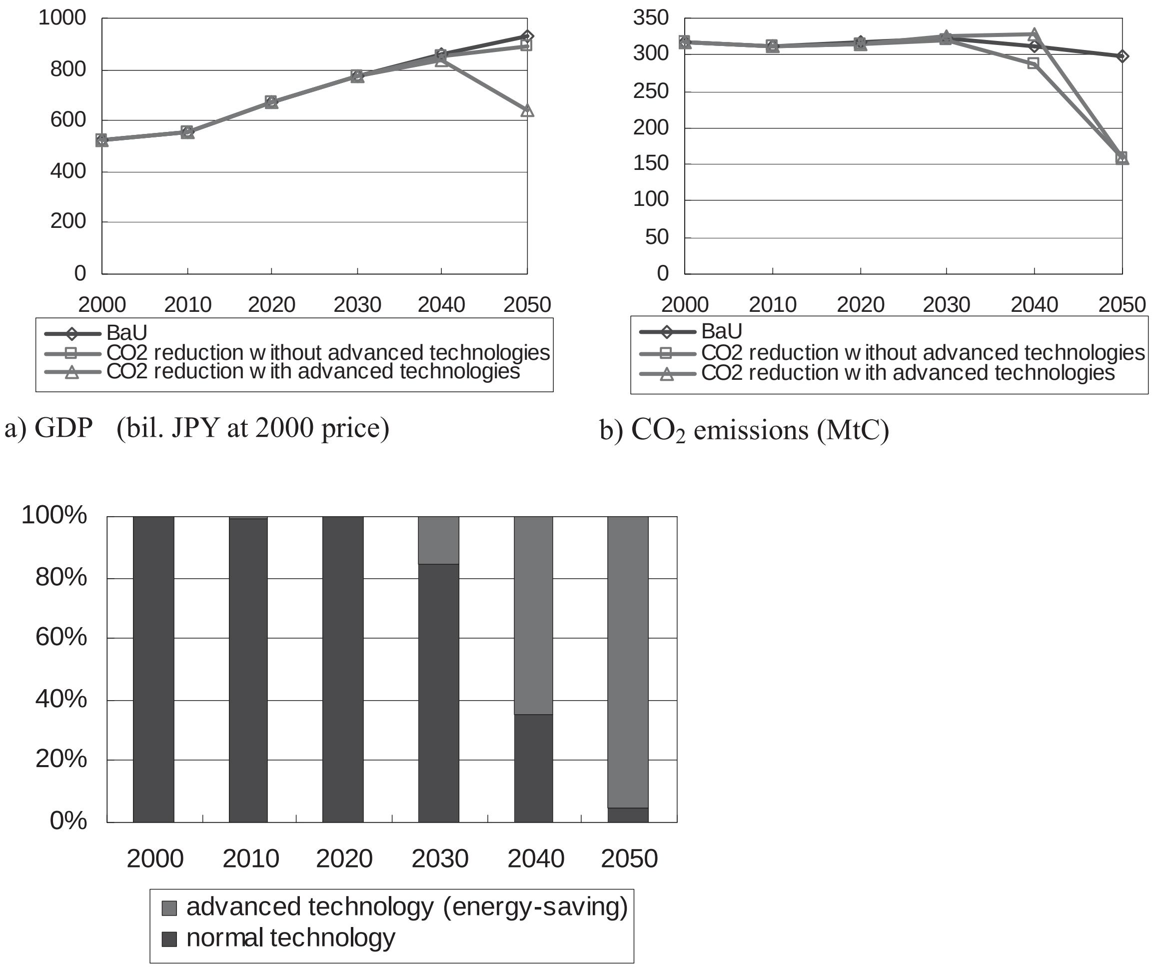
Fig. 4.4.2 Model structure.

Table 4.4.1 Sets of commodities, sectors, technologies, personalities, and environments (tentative)

Sets				Sub-sets		Sub-sub-sets		remarks
g	(	Goods	)	Energy	Energy goods or not	*e*	Energy goods	Including fossil fuels, renewable energy, final energy
						ne	Non-energy goods	
				Market	Marketable goods or not	*p*	Marketable goods	
						g	Public goods	Disaster prevention, transportation infrastructure, medical service etc.
						h	Household production goods	Including service in household
				Transport	Transport service or not	*t*	Transport service	Transport service in production sectors, public and household sectors
						nt	Non-transport service	
				Final	Potential final demand or not	*f*	Potential final demand goods	
						in	Non-potential final demand goods	
i	(	Institutional sector	)			*j*	Production sector	Private sectors
						g	Public sector	Government and public non-financial sector
						h	Household sector	
k	(	Technology	)					Technology is attributed to any sector.
p	(	Attribute	)	sex	sex	*m*	Male	
						f	Female	
				res	residential area	*d*	High density city	
						t	Traditional city	
						r	Rural city	
						n	Nature preserve	
				age	age	*00*	Under 14 years old	
						15	From 15 to 64 years old	
						65	65 years old and above	
				occ	work			Substitution with institutional sector
z	(	Environment	)	-	-	-	-	

4.4.3 Application to Japan

Fig. 4.4.3 shows the tentative simulation results using the simplified BCM. As shown in Fig. 4.4.3 (a), if energy-saving technologies cannot be introduced, then the GDP loss in 2050 will be enormous. On the other hand, if energy-saving devices can be selected, then advanced technologies will be selected, as shown in Fig. 4.4.3 (c), and the GDP loss will be small.



a) GDP (bil. JPY at 2000 price)

b) CO_2 emissions (MtC)

c) Technology share (%) for case of CO_2 emissions reduction with advanced technology

Fig. 4.4.3 Tentative simulation results using BCM.

5 Element model as a tool for social, economical and environmental development

5.1 AIM/CGE Model

5.1.1 Characteristics of AIM/CGE model

- AIM/CGE (computable general equilibrium) model is a static general equilibrium model for a single country.
- One of the purposes of this model is to present consistent visions for achieving a drastic CO_2 emissions reduction by 2050, taking into account the countermeasures assessed in the individual models explained in this booklet.

5.1.2 Structure of AIM/CGE model

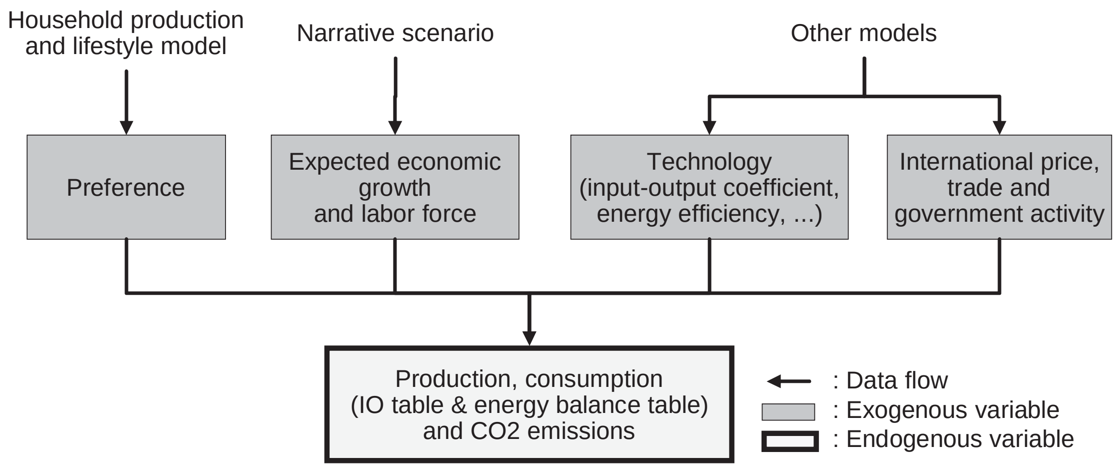
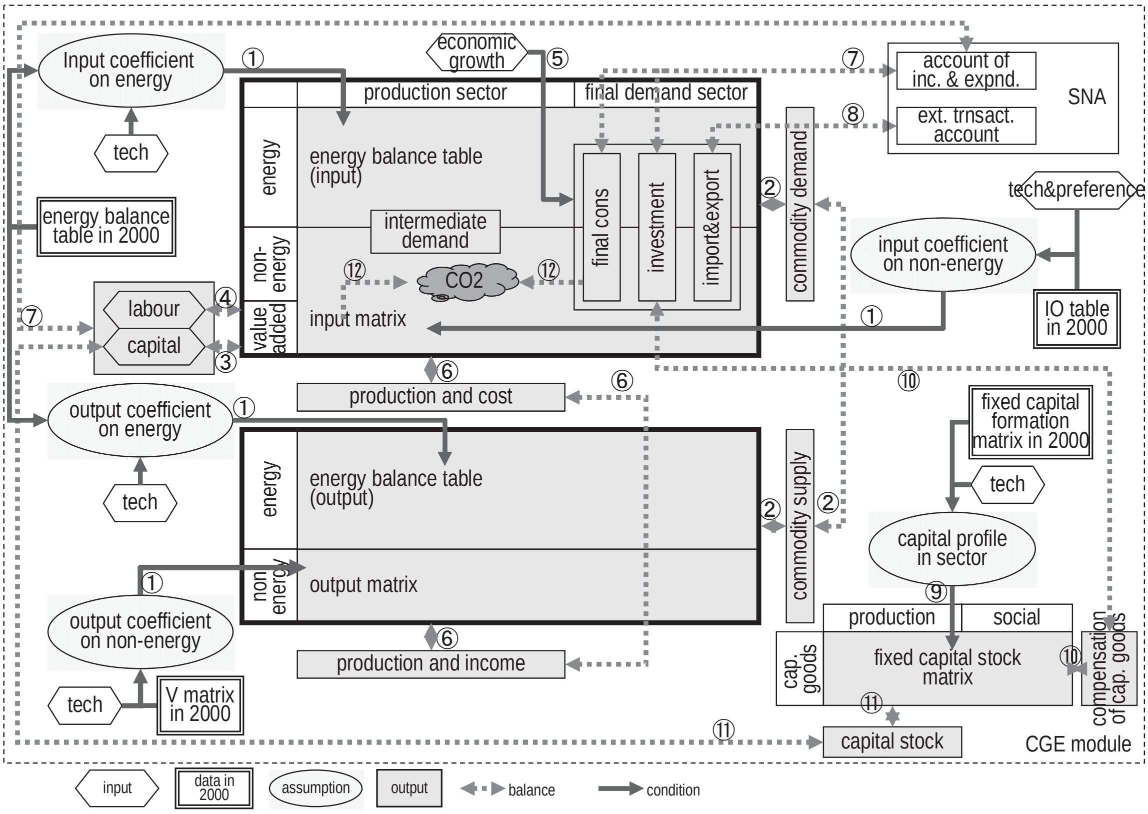


Fig. 5.1.1 AIM/CGE model flow chart.

The parameters in the AIM/CGE model are calibrated from the input-output data for 2000. The input data are updated in order to assess future economic activities from the narrative scenario, the models explained in this booklet, and other macroeconomic models representing future values related to the macro economy.

Input data include expected economic growth, labor endowment, capital endowment, technology improvement (input-output coefficient and energy efficiency), preference changes, ratio of imported goods to domestic goods, international prices, etc.

Based on the above input data, the commodity prices and activities are calculated to balance the demand and supply of each commodity. The outputs include the input-output table, energy balance table, and CO_2 emissions in the target year.



① production function	⑦ expenditures and income in households and government
② commodity market	⑧ assumptions for imports and exports
③ capital market	⑨ fixed-capital stock matrix
④ labor market	⑩ investment goods market
⑤ calculation of GDE	⑪ capital stock
⑥ expenditures and income in production sector	⑫ CO_2 emissions

Fig. 5.1.2 Structure of AIM/CGE model.

Although the basic data includes more than 100 classifications, the commodities and sectors are aggregated in order to meet research objectives. The Table 5.1.1 shows examples of aggregated activities and commodities.

5.1.3 Application to Japan

Fig. 5.1.3 shows the total output by sector in 2000 and 2050. “2050A” and “2050B” are simulation results reflecting “scenario A” and “scenario B,” respectively. The share of the service sectors will expand more rapidly in scenario A than in scenario B.

Table 5.1.1 Examples of aggregated activities and commodities in the AIM/CGE model

Activities

Primary industry	Agriculture / Forestry / Fishing
Mining	Coal mining / Crude oil and natural gas mining / Other mining
Manufacturing	Food products and beverages / Textiles / Pulp, paper and paper products / Publishing and printing / Chemical materials / Chemical products / Petroleum products / Coal products / Non-metallic mineral products / Pig iron and crude steel / Other steel products / Non-ferrous metal / Fabricated metal products / Machinery / Electrical machinery, equipment and supplies / Transport equipment / Precision instruments / Other manufacturing
Construction	
Power plant	Nuclear power plant / Thermal power plant / Hydro power plant / Geothermal plant / Photovoltaic generation / Wind power plant / Waste power plant / Biomass power plant
Town gas	
Water supply	
Service	Wholesale and retail trade / Finance and insurance / Real estate / Public service activities / Other service activities
Transport and communications	Railway transport / Road transport / Water transport / Air transport / Other transport / Communications

Commodities

Primary energy	Coal / Crude oil / Natural gas / Nuclear / Hydro / Geothermal / Photovoltaic / Wind / Waste / Biomass
Secondary energy	Coaks / Other coal products / Gasoline / Naphtha / Jet fuel / Kerosene / Light oil / Heavy oil / LPG / Other petroleum products / Town gas / Electricity / Hydrogen / Heat
Primary industry	Agriculture / Forestry / Fishing
Other mining	
manufacturing	Food products and beverages / Textiles / Pulp, paper and paper products / Publishing and printing / Chemical materials / Chemical products / Non-metallic mineral products / Pig iron and crude steel / Other steel products / Non-ferrous metal / Fabricated metal products / Machinery / Electrical machinery, equipment and supplies / Transport equipment / Precision instruments / Other manufacturing
Construction	
Water supply	
Service	Wholesale and retail trade / Finance and insurance / Real estate / Public service activities / Other service activities
Transport and communications	Railway transport / Road transport / Water transport / Air transport / Other transport / Communications

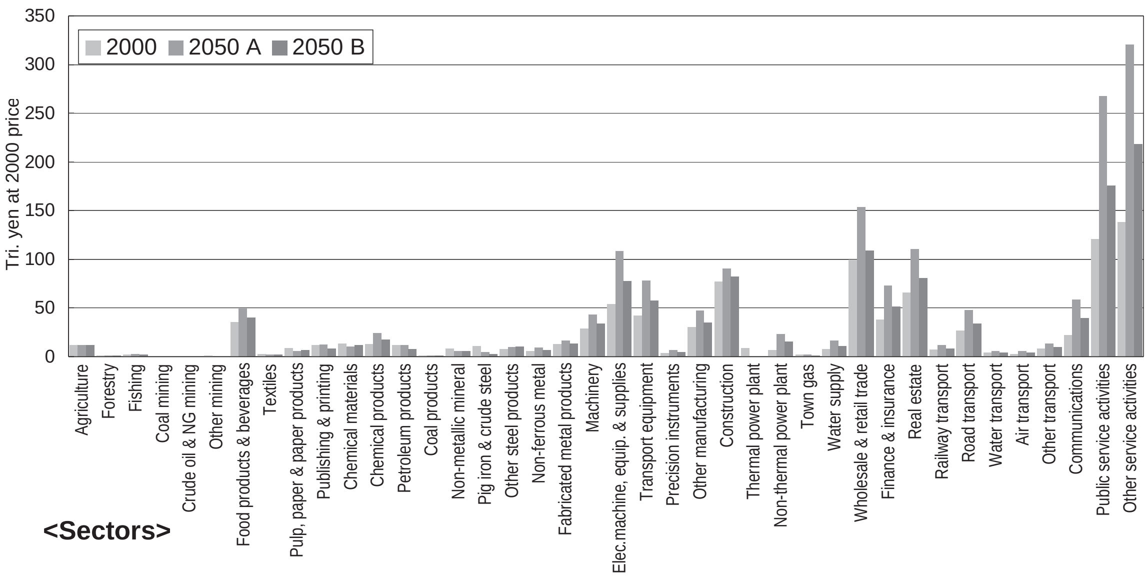


Fig. 5.1.3 Total output by sector in 2000 and 2050.

5.2 AIM/Population and Households Model (PHM)

5.2.1 Characteristics of PHM

The population and households model (PHM) simulates the future province-wise population by age and sex, giving exogenously nation's and province-wise base year's population, expected life table, expected fertility rate, expected migration rate. The number of households by family type is also calculated with headship rate method

Moreover it simulates population and households by climate zone and land-use classification with the detail assumption of population distribution.

5.2.2 Structure of PHM

Fig. 5.2.1 shows the flow chart used for estimating future population and households. The cohort component method is used. Each birth cohort is calculated with fertility rate, life table and migration rate. It states that the population at the next time interval (interval "t + 1") is the population at the beginning time interval ("t") plus the net natural increase (or decrease) plus the net migration. Base year's population, expected life table, expected fertility rate and expected migration rate are given exogenously. When there are inconsistency between nation's parameters and province-wise parameters, we modify the province-wise parameters in order to consist with national ones.

The headship rate method is used for projecting the number of households. The headship rate is the percentage of households head within the population. We assume the number of head is equal to the number of the households. We use the historical dynamics of headship rate change as the basis of calculation and modify the parameter to reflect assumed social change.

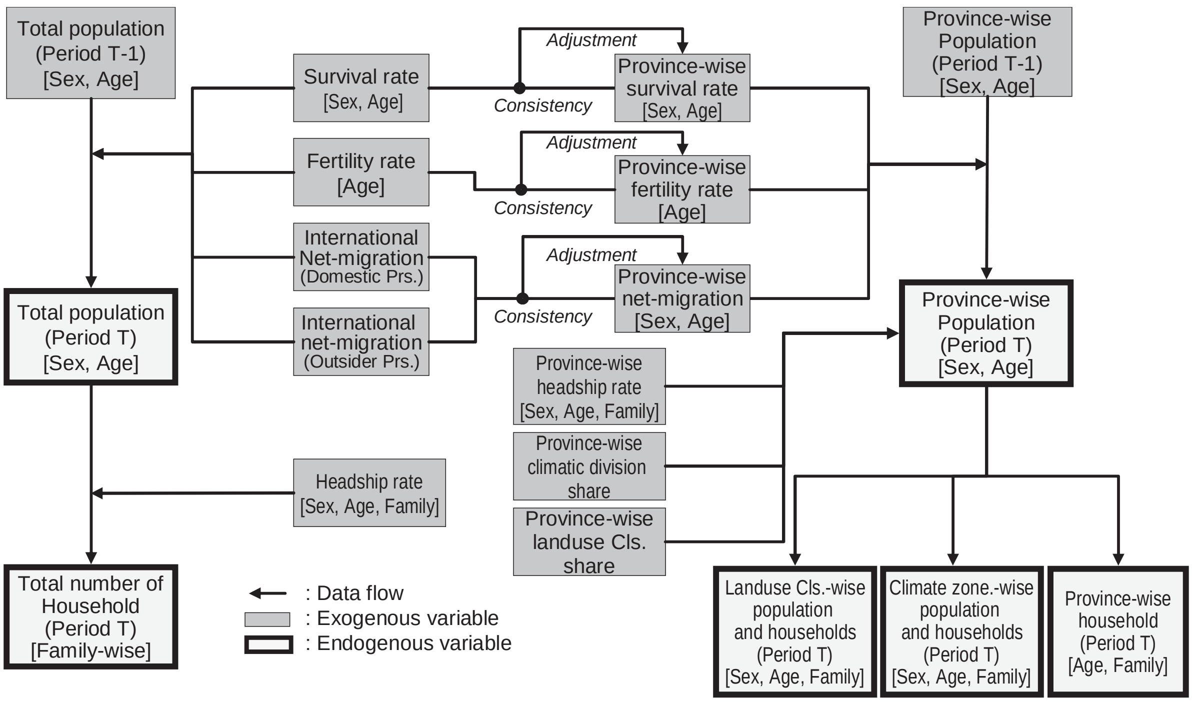


Fig. 5.2.1 Population and Household Model flow chart.

Number of households by climate zone and population by land-use class are estimated with the assumption of today's population distribution in a prefecture.

The indices of the PHM are listed in Table 5.2.1

Table 5.2.1 Indices of Japan's PHM

Indices	Classification	Elements
Age	19	Birth, 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85-
Sex	2	Male, Female
Family	5	One-person, Couple-only, Couple-Children, Parent-Children, Others
Province	47	(all prefectures)
Climate	6	I (Hokkai), II (Aomori, Iwate, Akita), III (Miyagi, Yamagata, Fukushima, Tochigi, Nagano, Niigata), IV (except I-III,V,VI), V (Miyazaki, Kagoshima), VI (Okinawa)
Land-use	10	i. Three largest metropolitan area: i-1. Cities, i-2 Lowland farming, i-3 Intermediate & mountainous area ii. Hub cities: ii-1.Cities, ii-2.Lowland farming, ii-3.Intermediate & mountainous area iii. Prefectural hub cities iv. Others: iv-1.Cities, iv-2.Lowland farming, iv-3.Intermediate & mountainous area

5.2.3 Application to Japan

Fig. 5.2.2 shows an example of simulation output. Japan's future population will decrease by about 20% compared to the current level. Population will trend to concentrate in Tokyo metropolitan area. As for households, the share of "one person" family will increase.

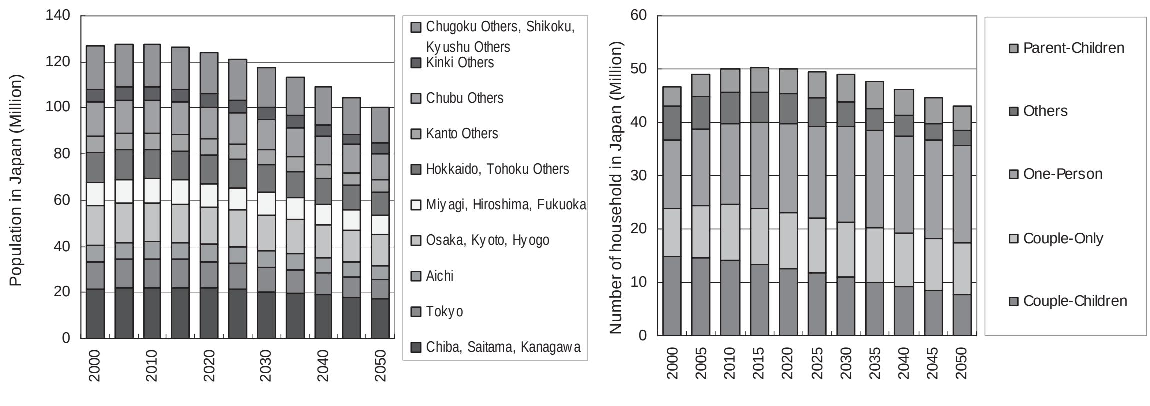


Fig. 5.2.2 Example of output from the Population and Households Model.
(Left: Region-wise population, Right: Number of households by family type)

5.3 AIM/Building Dynamics Model (BDM)

5.3.1 Characteristics of BDM

The Building Dynamics Model uses the cohort component method to estimate the number and the floor space of future dwelling stock from the dwelling stock in the base year, the residual ratio and construction of the new dwellings. The model is able to estimate the number and the floor space of future dwelling stock by region, building type, and construction period according to the population distribution, types of new dwellings, retrofit of existing dwelling stock, and the residual ratio of dwelling stock.

5.3.2 Structure of BDM

a) Input

Users enter the region, building type, years since construction, and years of simulation as elements of the indices in line with purpose of analyses and data availability. Table 5.3.1 shows the elements of the indices in simulations of Japan by the AIM Japan team. Table 5.3.2 shows the exogenous parameters in the BDM.

Table 5.3.1 Element of indices

Indices	Indices in the BDM	Example of element in simulations of Japan
Region (province)	I	47 prefectures
Region (climate)	C	6 zones
Building type	J	16 types
Years since construction	N	100 years
Years of simulation	T	Every year from 2003 to 2050

Table 5.3.2 Exogenous parameters in the BDM

Exogenous parameters	Code in the BDM
Number of dwelling stock in the base year	ND_P_Base(I,J,N)
Residual ratio	Rs(J,N,T)
Number of households	NH(T)
Proportion of number of dwelling stock to number of households	HQH(T)
Region distribution of new dwellings	Ds_P(I,T)
Building type distribution of new dwellings	Ds_T(I,J,T)
Retrofit of existing dwelling stock	Rf(J,J1,N,T)
Average floor space of new dwellings	AFS_N_P(I,J,T)

b) Output

The BDM output is shown in Table 5.3.3

Table 5.3.3 BDM output

BDM output	Code in the BDM
A. Number of dwelling stock	
Number by province and building type	ND_P_TO1
Number by building type and years since construction	ND_P_TO2
B. Floor space of dwelling stock	
Area by province and building type	FS_P_TO1
Area by building type and years since construction	FS_P_TO2

c) Calculation flow

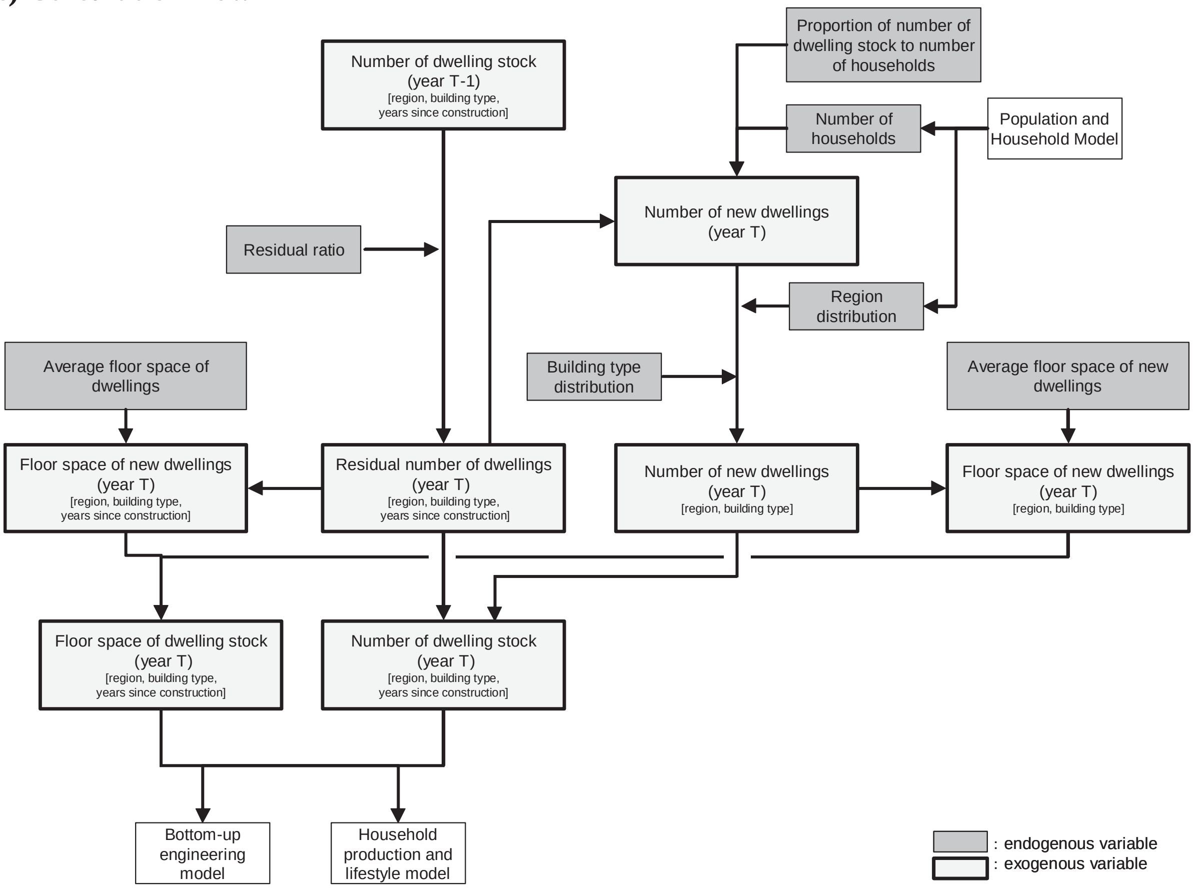


Fig. 5.3.1 BDM flow chart.

The dwelling stock is calculated by adding the new dwellings to the residual dwelling stock from the previous year. The dwelling stock in the base year is determined from statistics. (The BDM for Japan is from the 2003 Housing Survey by the Ministry of Internal Affairs and Communications.) The residual ratio is a Weibull distribution. (The residual ratio in the BDM for Japan is estimated from housing surveys conducted in 1978, 1983, 1988, 1993, 1998, and 2003.) The demand for dwelling stock is determined in proportion to the number of households in the Population and Household Model. This determines the number of new dwellings that need to be built in order to meet demand. Then, this is multiplied by region distribution, building type distribution. Finally, the dwelling stock by region, building type, and construction period are calculated by adding the new dwellings to the residual dwelling stock. Retrofit of existing dwelling stock could also be considered depending upon the scenario. After estimating number of dwelling stock, total floor space of dwelling stock is calculated by multiplying number of dwelling stock and average floor space by region, building type and years since construction.

5.3.3 Application to Japan

The results of example simulations are shown below. BDM Japan uses 16 building types with 2 types of dwellings, 2 types of construction materials and 4 insulation levels. Therefore these results are aggregated and focus on construction material and insulation level. Fig. 5.3.2 shows the estimated future dwelling stock by construction material. After peaking in 2015, the dwelling stock decreases, reflecting a decrease in the number of households. Fig. 5.3.3 shows the estimated future dwelling stock by insulation level. Insulation retrofitting is responsible for the rapid growth beginning in 2020 for the “1999 standard”. About a quarter of current dwellings will still exist in 2050, therefore to make all the dwelling stock meet “1999 standard” in 2050, it is essential to not only enhance the insulation of new dwellings but also retrofit old dwellings with insulation.

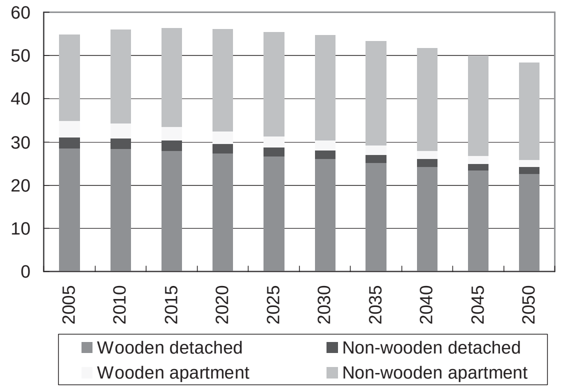


Fig. 5.3.2 Estimated number of dwelling stock by construction material (millions).

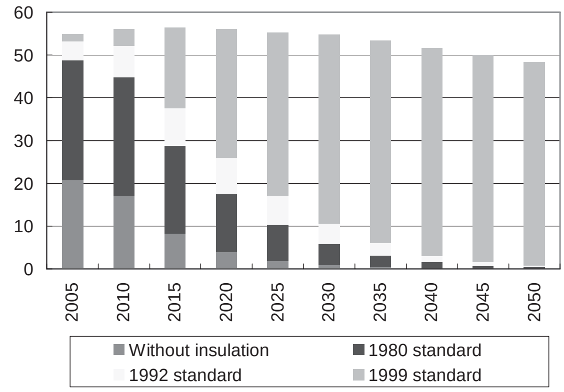


Fig. 5.3.3 Estimated number of dwelling stock by insulation level (millions).

5.4 AIM/Transportation Demand Model (TDM)

The Transportation Demand Model (TDM) is composed of the Passenger Transportation Demand module (TDM_P) and the Freight Transportation Demand module (TDM_F).

5.4.1 Characteristics of TDM_P

- The Passenger Transportation Demand Model (TDM_P) simulates transportation demand associated with changes in population distribution, social environment, personal activity patterns, modal share, and average trip distance. It is based on the transportation model developed by Japan's Ministry of Land Infrastructure and Transport (MLIT).
- In Japan, transportation demand within the daily living area (intra-region transportation) is calculated separately from transportation demand between the daily living areas (inter-region transportation).

5.4.2 Structure of TDM_P

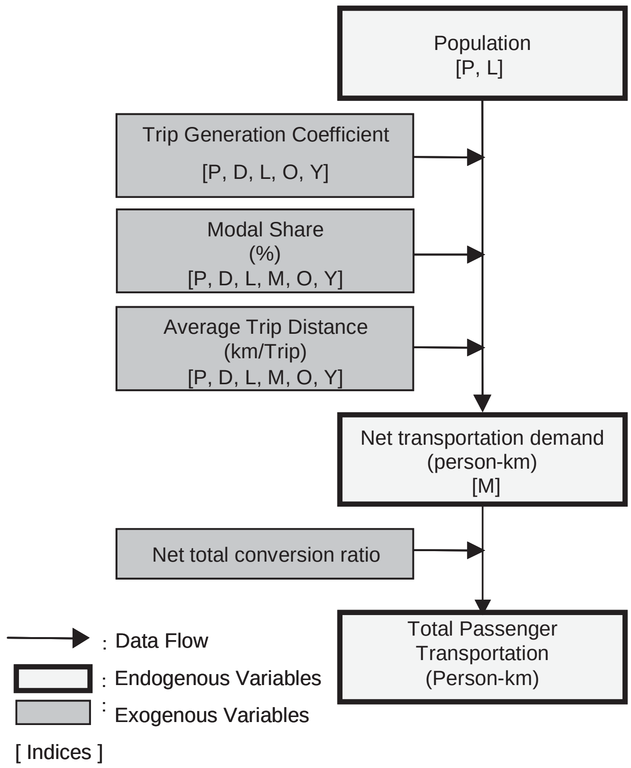


Fig. 5.4.1 TDM_P flow chart.

The model structure is quite straightforward and the parameters required in the model can be obtained from national "person-trip" survey data. The population data is classified by attribute and calculated using the license holding ratio, employment rate, outputs from the Population and Household Model (PHM), etc. Changes in the trip generation coefficient, modal share, and average trip distances for the year in question are assumed from scenarios. Next, the population data classified by attribute is multiplied by the parameters. Finally, the transportation demand is calculated. Exogenous variables used in the models include trip generation coefficient, modal share, and average trip distance. The following table shows the classifications of the variables used for the simulation.

Table 5.4.1 Classifications of variables in TDM_P

Indices	Indices in TDM_P	Example of element
Personal attribute	P	Several groups depending on age, sex, employment, etc.
Day	D	Weekday, holiday
Land area	L	Urban, mountainous, agricultural, etc.
Mode	M	Car, bus, railway, aviation, maritime, walking & bicycling, etc.
Objective	O	Work, school, return, business, private & shopping, etc.
Simulation time	Y	Every 5 years between 2000 and 2050

5.4.3 Application to Japan (TDM_P)

The following figures show sample outputs of a simulation for Japan. As shown in Fig. 5.4.4 and Fig. 5.4.5, although the total transportation demand is decreasing, the per capita transportation demand remains constant. The reason for such a low growth rate for per capita transportation demand is the decrease in average trip distance associated with changes in urban structures. The share for railway transportation will increase rapidly due to the promotion of a modal shift from car to train.

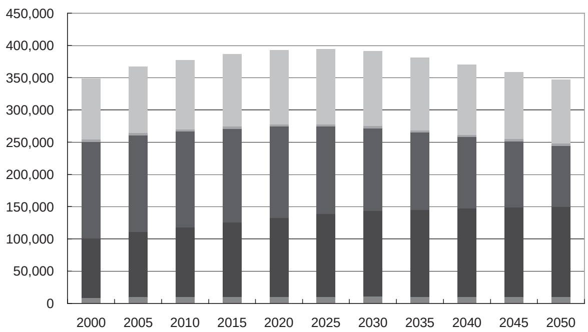


Fig. 5.4.2 Inter-region transportation demand by mode of transportation (mil. person-km).

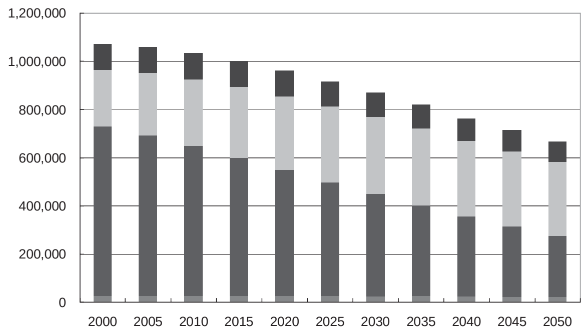


Fig. 5.4.3 Intra-region transportation demand by mode of transportation (mil. person-km).

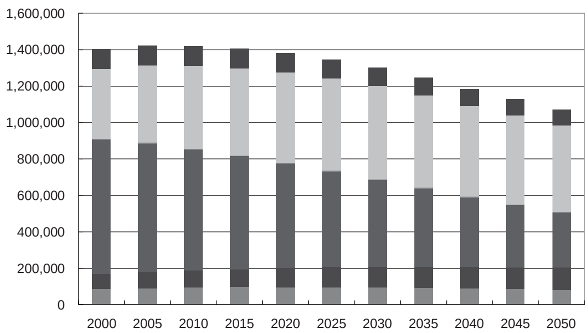


Fig. 5.4.4 Total transportation demand by mode of transportation (mil. person-km).

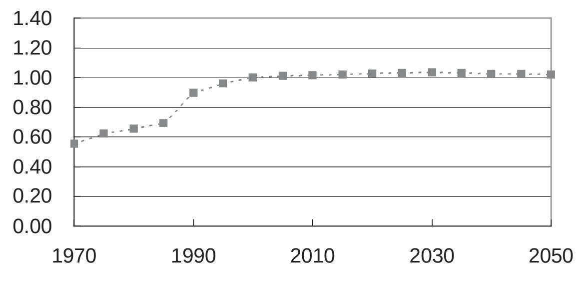


Fig. 5.4.5 Total transportation demand per capita (mil.person-km/cap).

■Bus ■Aviation ■Pass.car ■Maritime ■Railway ■Walking & Bicycling

5.4.4 *Characteristics of TDM_F*

- The Freight Transportation Demand Model (TDM_F) simulates the freight transportation volume associated with changes in the industrial structure, material density, transportation distance, and modal share.
- The inputs of the model are production and imports calculated by the CGE Model.
- The outputs are freight transportation volumes in terms of tonne-km by mode.

5.4.5 *Structure of TDM_F*

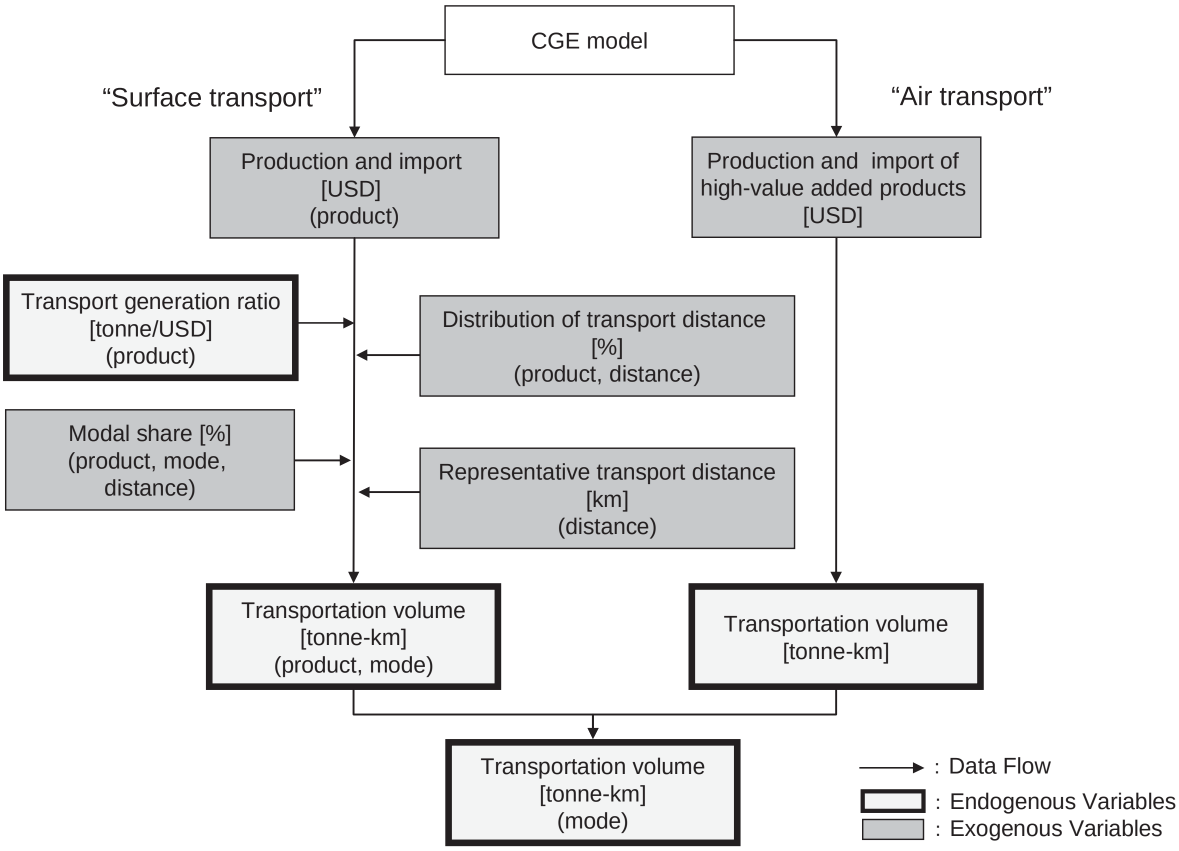


Fig. 5.4.6 TDM_F flow chart.

Different flows are used for surface and air transport. For surface transport, the transportation volume in terms of tonnes is calculated by multiplying gross production (domestic production + imports) by the transport generation ratios. Next, the transportation volume in tonnes for each transport distance is calculated using the distribution of transport distance. The transportation volume in tonnes of each mode of transport is then calculated using the modal share for each transport distance band. Finally, the transportation volume in terms of tonne-km is calculated using the representative transport distance of each distance band. The transport generation ratios are estimated endogenously using regression equations identified from historical data. The distribution of transport distance, the modal share, and the representative transport distance of each distance band are given exogenously.

For air transport, the transportation volume in tonne-km is directly calculated from production and imports of high-value added products.

Table 5.4.2 Indices of TDM_F

Indices	Elements
Mode	Small freight vehicle, large freight vehicle, railway, maritime, aviation
Product	Agricultural products (AG), minerals (MI), metals and machinery (ME), chemicals (CH), light-industry products (IL), miscellaneous industry products (IM), specialty products (SP), others (OT)
Transport distance band	~100 km, 100~300 km, 300~500 km, 500~750 km, 750~1000 km, 1000 km~

5.4.6 Application to Japan (TDM_F)

The following figures show sample outputs of the simulation. It is assumed in scenarios A and B that the sums of production and imports for the primary and secondary sectors in 2050 are 1.43 and 1.10 times those for the year 2000, respectively. It is estimated that the total transportation volumes in tonne-km in scenarios A and B are only 0.91 and 0.79 times those for the year 2000 (Fig. 5.4.10). This is partly because of a decrease in the proportion of fundamental materials in production and imports. Another factor is the reduced weight of each unit of product. These effects can be seen in the reduced weight of the transportation volume (Fig. 5.4.7). As for the transportation volume by transport distance, short-distance transport retains a large share (Fig. 5.4.9), resulting in a large modal share for freight vehicles (Fig. 5.4.8), which have an advantage over other modes for short-distance transportation.

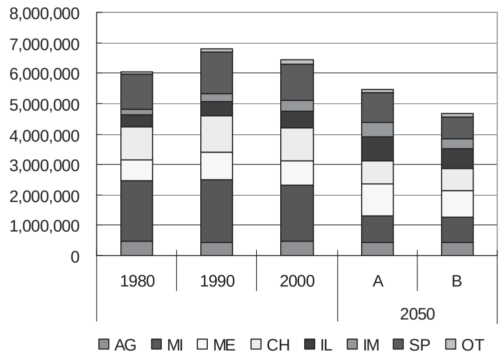


Fig. 5.4.7 Transportation volume in tonnes by product (1000 tonnes).

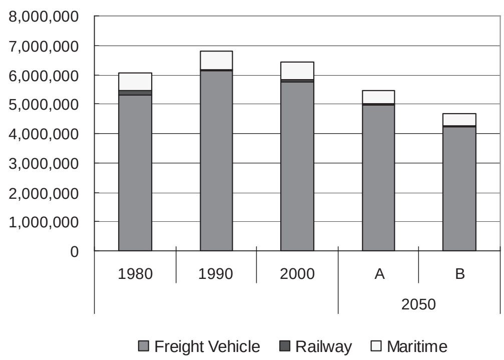


Fig. 5.4.8 Transportation volume in tonnes by mode (1000 tonnes).

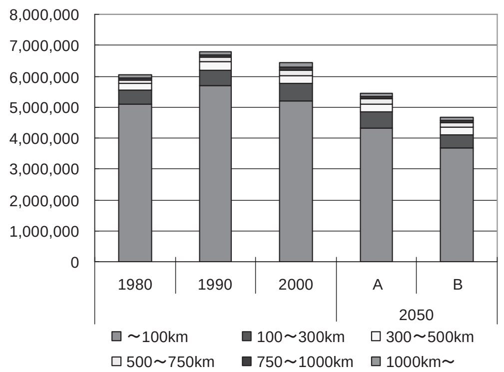


Fig. 5.4.9 Transportion volume in tonnes by transport distance (1000 tonnes).

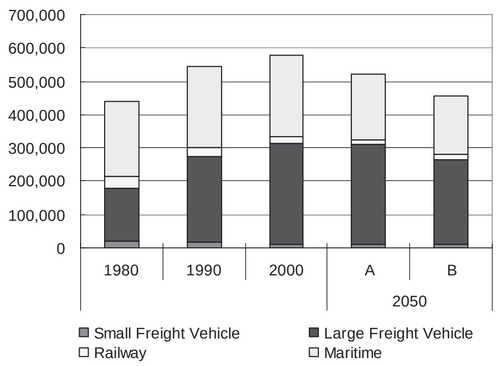


Fig. 5.4.10 Transportion volume in tonne-km by mode (mil. tonne-km).

5.5 AIM/Material Stock and Flow Model (MSFM)

5.5.1 Characteristics of MSFM

- Material Stock and Flow Model (MSFM) estimates the change of material stocks and flow in the society. The factors considered in the model are final consumption and investments which are affected by capital stocks, material densities of goods, physical input output coefficients of production sectors, and recycling rate of wastes.
- The input data of this model is the final demand calculated by an economic model (Macroeconomic model). The outputs are material flow among sectors, the flow between economic activities and the environment, and material stocks accumulated as production capital, waste accumulation, and so on.
- The MSFM analyzes the mechanism of changes in material stocks and flow, and the effect of recycling materials in the future society, and looks for the measures towards the LCS in connection with material consumption.

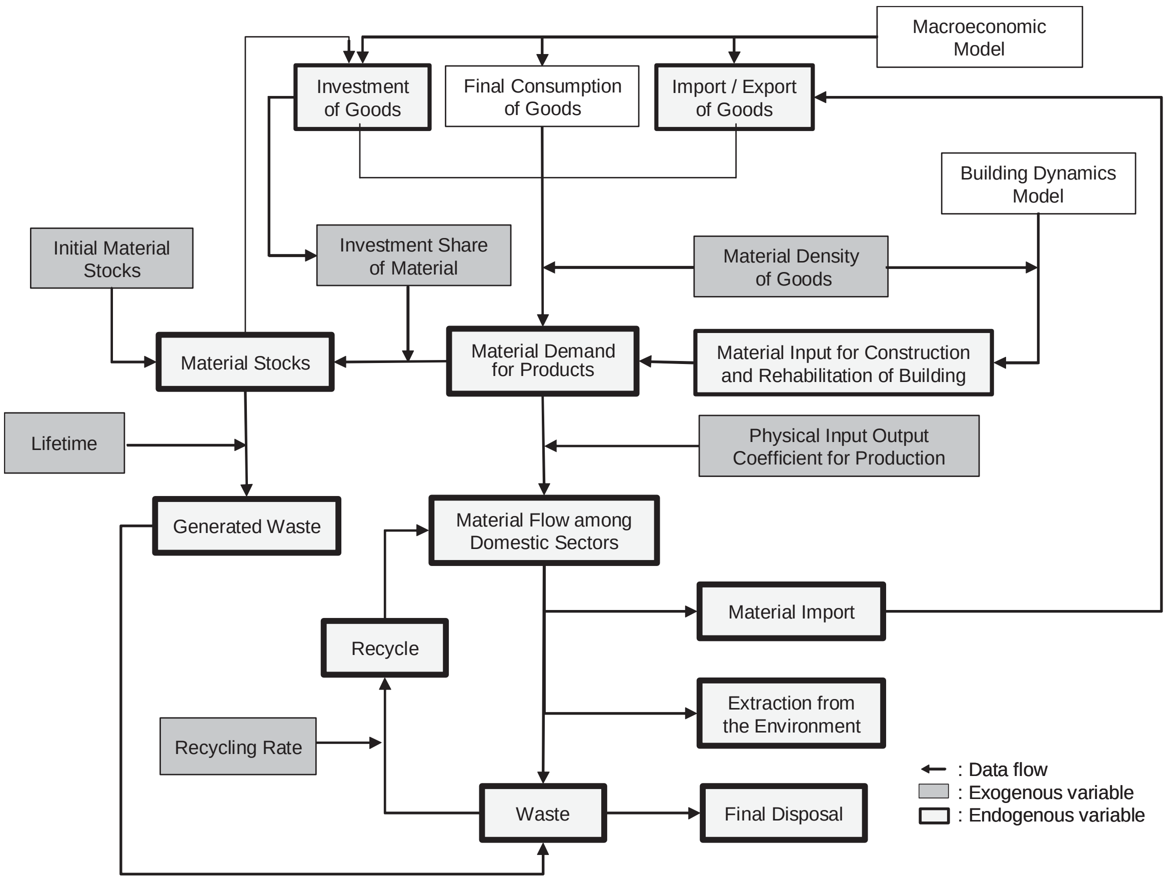


Fig. 5.5.1 Flow chart for projecting future material stocks and flow.

5.5.2 Structure of MSFM

The model was calibrated with the past 30 years' socio-economic data, the material stocks data, and production data. As for the socio-economic data, population, the number of households, the amount of investment, GDP, and import and export were considered. As for material stocks and productions, floor area of dwellings, the number of car ownership, steel and cement production, *etc*, and other factors were taken into account. Using these relational expressions and the future estimates of socio-economic indices, demands for future stocks of durable goods in each year are estimated. From the difference between the demand for stocks and the existing stocks, the required investment is calculated. The material demand for products, the driving force of the MSFM, is calculated by multiplying the volume of goods production by their material density. Here, "Material Density" is defined as the weight of material per unit (tonne per unit monetary amounts, tonne per vehicle, tonne per m^2, *etc*). Material input for construction and rehabilitation of buildings which are the output from the Building Dynamics Model, is also the driving force for the MSFM.

The amount of stocks is determined by adding new investments in the previous period and subtracting the depleted portion. Initial material stocks are estimated by accumulating material inputs over the past 100 years.

The material flow among domestic sectors and the flows related to the extraction from the environment and the disposal into the environment are estimated based on the concept of material balance of goods and sectors while considering parameters such as changes in the material density of the goods, changes in physical input-output coefficients of production sectors by technology innovation, and changes in the recycling rate of materials and lifetimes of durable goods. Flows related to the extraction from the environment and the disposal into the environment is also estimated.

Table 5.5.1 Classification of materials, goods, sectors

Indices	Elements
Material	Iron, Cement, Woods, Aluminum
Goods	Building, Civil engineering structure, Machinery, Others
Consumer goods	Goods which lifetime is less than 1 year
Durable goods	Goods which lifetime is more than 1 year
Sectors	Production sectors, final demand sectors
Production	Primary process (Pig iron), Secondary process (Crude steel), Tertiary production (Final steel products), Final goods production *( ) Example of iron case
Final demand	Households, Government, Investment, Import and Export
Waste	Ash, Old paper, Waste wood, Waste textile, Iron scrap, other metal, Slag, construction waste, other
Simulation time	1 year

5.6 AIM/Energy Supply Model (ESM)

5.6.1 Characteristics of ESM

- The Energy Supply Model (ESM) seeks optimum configurations of the energy system based on the energy balance between supply and demand, in order to take full advantage of renewables in specific regions.
- When exploring future energy systems, the model can shed light on the micro-grid and/or stand-alone generators, such as diesel engine generators, gas engine generators and combined heat and power systems (CHP).
- In terms of installation, maintenance, and mass production, renewable energy components comprise wind turbines, photovoltaics, woody biomass CHP systems, and solar heating.

5.6.2 Structure of ESM

a) Input

The model requires three types of data as exogenous variables: (1) the system component's costs, such as capital costs, operation and maintenance costs, and fuel costs; (2) the component's technological performance, such as thermal efficiencies, service life, and energy quality; and (3) resource data for renewables, such as wind patterns, amount of solar insolation, and the availability of woody materials in the region.

b) Output

The major findings of the model are: the optimum capacity of each system, energy consumption, total energy system cost, and CO_2 emissions.

c) Calculation flow

Fig. 5.6.1 is a schematic diagram of the ESM. The model mainly covers energy system in the residential and commercial sectors. The energy demands are determined by other model elements, i.e., Population and Household Model (PHM), Building Dynamic Model (BDM), Household Production and Lifestyle Model (HPLM), and Energy Snapshot Tool (EST). In order to enhance the effectiveness of the renewable system, the model has energy storing capacities, such as batteries and/or hydrogen storage. Data for natural resources, such as wind patterns and amount of solar insolation are from actual observations.

The optimum energy system will be configured according to regional characteristics. System configuration is done in a linear optimization framework in which the system cost is minimized under several constraints such as energy demand supply balance, renewable energy supplies, and CO_2 emissions.

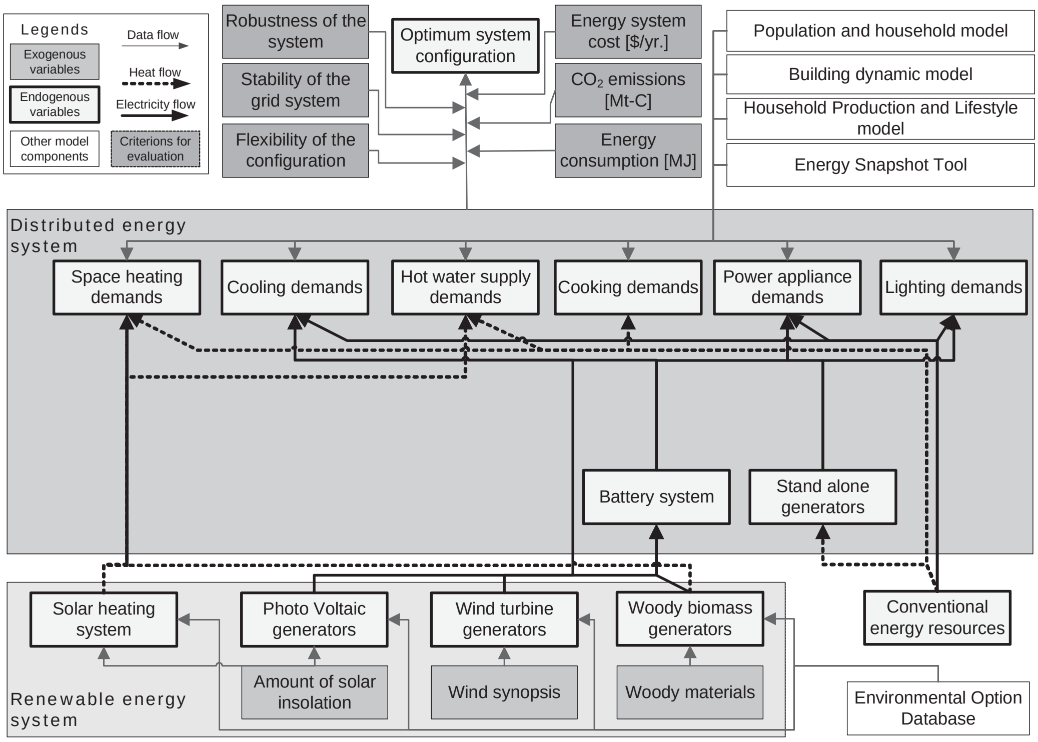


Fig. 5.6.1 Energy Supply Model flow chart.

5.6.3 Examples of Simulation Results

Results for two scenarios for electricity supply in an independent energy system are shown in Fig. 5.6.2 (scenario without battery) and Fig. 5.6.3 (scenario with battery).

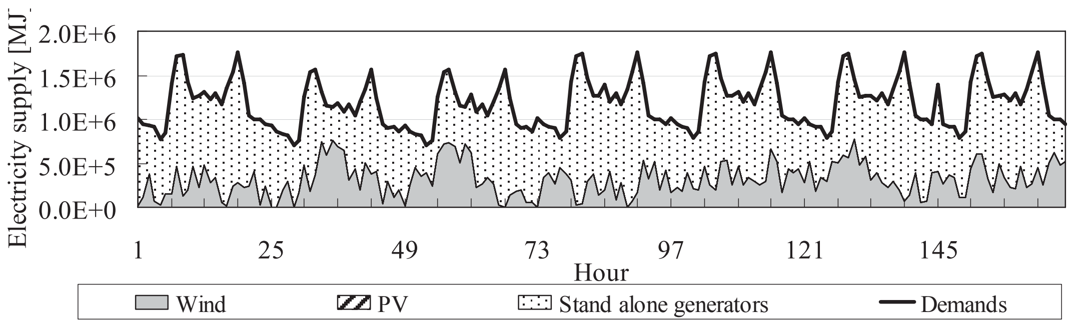


Fig. 5.6.2 Electricity generation in August, 2050 (scenario without battery).

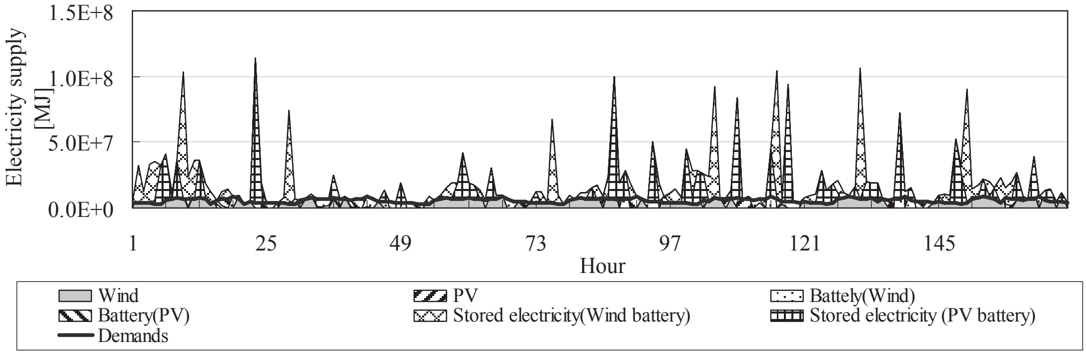


Fig. 5.6.3 Electricity generation in August, 2050 (scenario with battery).

5.7 AIM/Household production and lifestyle model (HPLM)

5.7.1 Characteristics of HPLM

- The Household Production and Lifestyle Model (HPLM) simulates energy service demand, waste generation, and water consumption for household production by four household types, under prescribed scenarios of household composition, age composition, income budget, and time budget in the future.
- The model can consider demographic and socioeconomic trends with consistency, together with Population and Household Dynamic Model (PHM), Building Dynamics Model (BDM) and Inter-sector and macroeconomic model.

5.7.2 Structure of HPLM

Fig. 5.7.1 shows the flow chart of HPLM. This model consists of two modules; “goods and service preference module” and “material and energy balance module”. “Goods and service preference module” estimates the final consumption expenditure from disposal income, household stock, and time use; it also estimates production of household service with the final consumption expenditure. “Material and energy balance module” estimates environmental load generations by the household service production.

In the model, disposal income is divided between final consumption expenditure and saving. Final consumption expenditures are spent on goods and services which are required for the household production. Preferences of goods are estimated with the historical household survey. The same is done for the time use budget. Produced household benefits are classified into nine categories, and about 400 kinds of goods, time use, and household capital stock are modeled as the inputs for the production in a nesting structure.

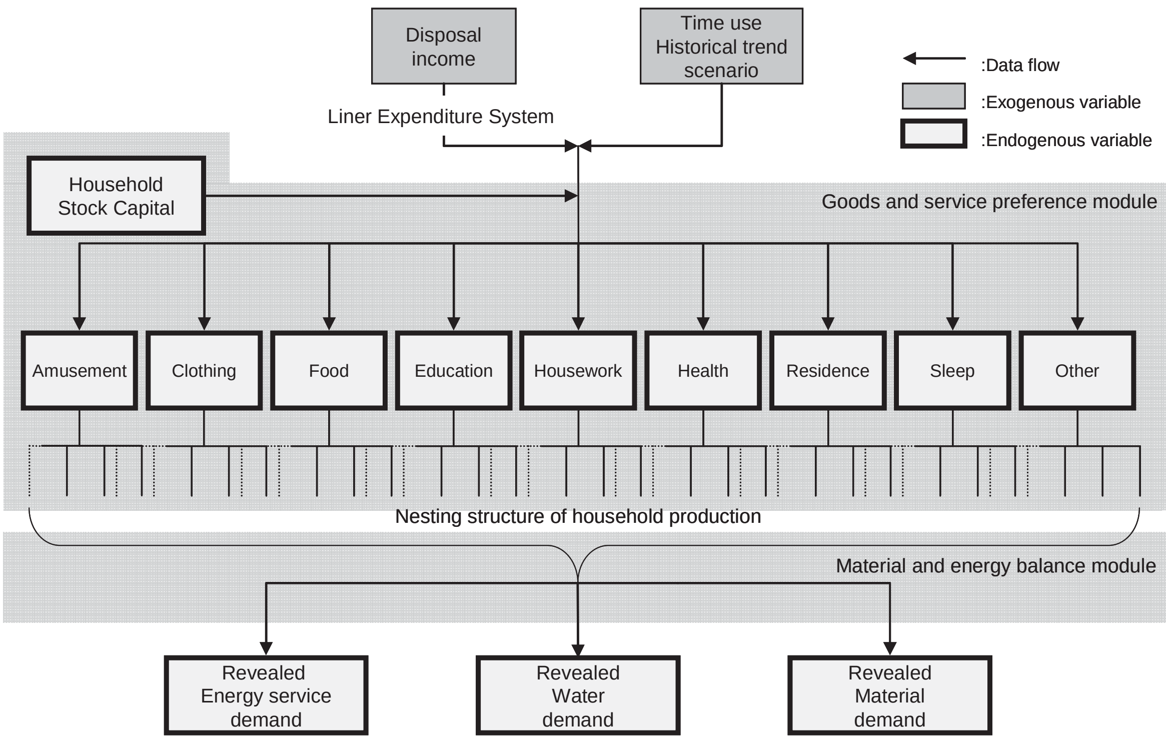


Fig. 5.7.1 Flow chart of HPLM.

Furthermore, required energy service demand, water demand and material demand for household production are summed up, considering time delay, conversion waste, and other factors, in order to calculate the generation of environmental loads.

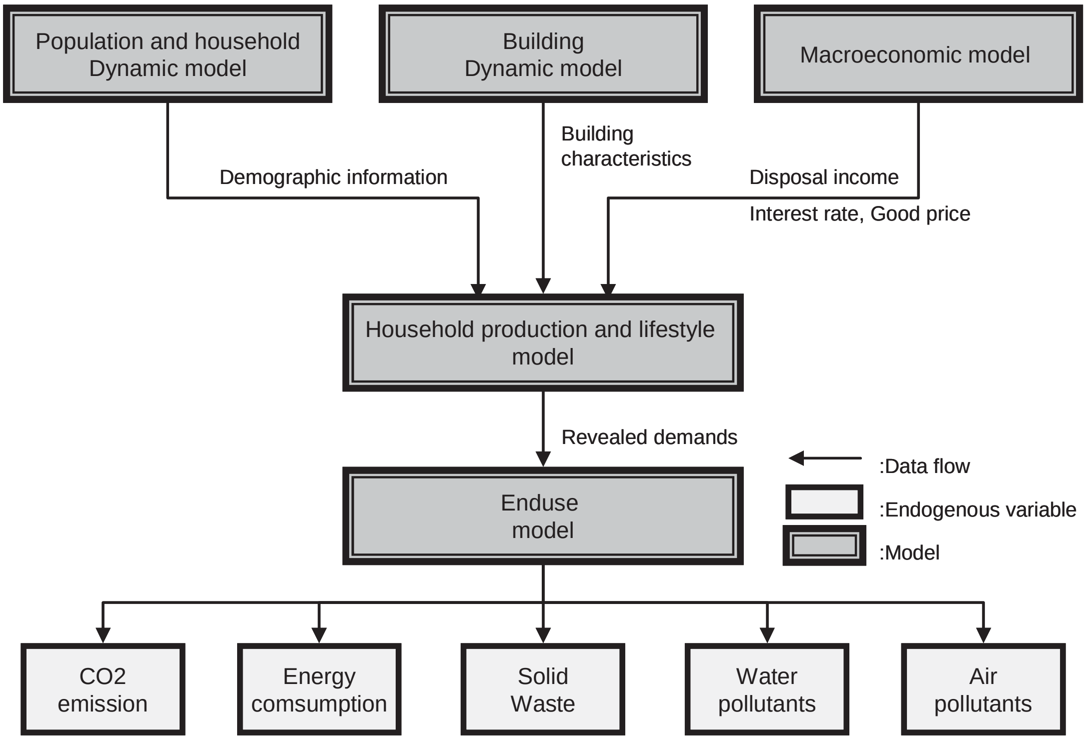


Fig. 5.7.2 Frameworks of HPLM and other models.

5.7.3 Example of Simulation Result

Fig. 5.7.3shows the growth of the household consumption expenditure by 2030. The growth of “one- person” household consumption expenditure is larger than that of “couple-only, couple-children” or “parent-children” household consumption expenditure. In Fig. 5.7.4, CO_2 emissions by residential energy consumption and by transport activity for household production is shown.

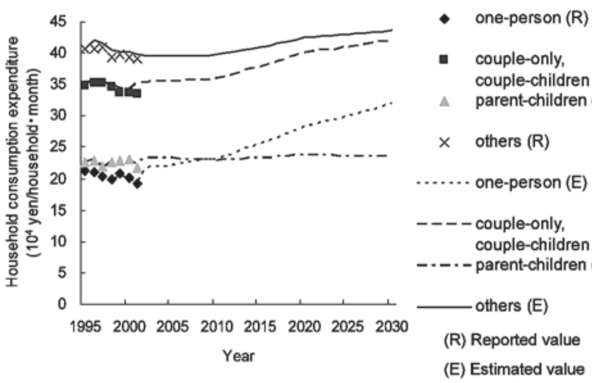


Fig. 5.7.3 Household consumption expenditure.

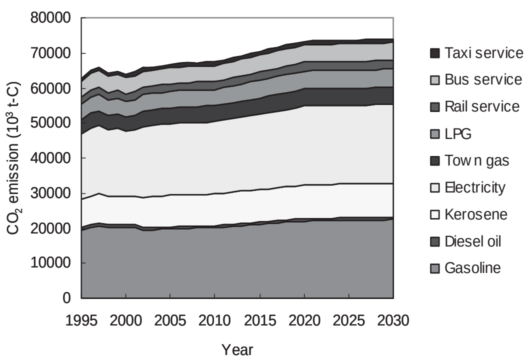


Fig. 5.7.4 CO_2 emission from household activities.

5.8 AIM/Water Management Model (WMM)

5.8.1 Characteristics of WMM

- As shown by the Water Management Model (WMM) in Fig. 5.8.1, water management can quantitatively assess the means of achieving the targets for access to safe water and sanitation.
- This model is a bottom-up type model based on the future diffusion of technologies for water supply and sanitation facilities. The model:
    - can estimate various combinations of technologies according to objectives and policies, in view of the wide divergence in diffusion costs and household water demand due to differences in diffusion of technologies for water supply and sanitation facilities.
    - can estimate future household water demand taking the effects of water-saving measures into consideration and,
    - can estimate the relative risk of diarrheal mortality based on the safe water and sanitation coverage.

5.8.2 Model flow Chart

The WMM needs basic “year” data such as socio-economic data, safe water and sanitation coverage data~~,~~ and unit data. As for socio-economic data, urban population and rural population, along with GDP are provided. The safe water and sanitation coverage data by technology in urban and rural areas are categorized based on the information in Table 5.8.1 compiled by the World Health Organization and UNICEF. The unit data includes unit cost and unit water demand. The unit cost data consists of initial and recurrent cost for each water supply and sanitation technology. Each water supply and sanitation technology has its own unit water demand. When future targets of water supply and sanitation coverage are established, necessary initial and recurrent cost, water demand and relative risk of diarrheal mortality are calculated. If investment costs are constrained under the future target of total access to safe water and sanitation (note boxes circulated by curved arrowed-lines in Fig. 5.8.1), each water supply and sanitation technology coverage is endogenously decided in accordance with the dissemination procedures. The relative risk of diarrheal mortality is calculated based on the condition of access to safe water and sanitation by technologies excluding present condition and other related factors (medical, dietary, climate condition).

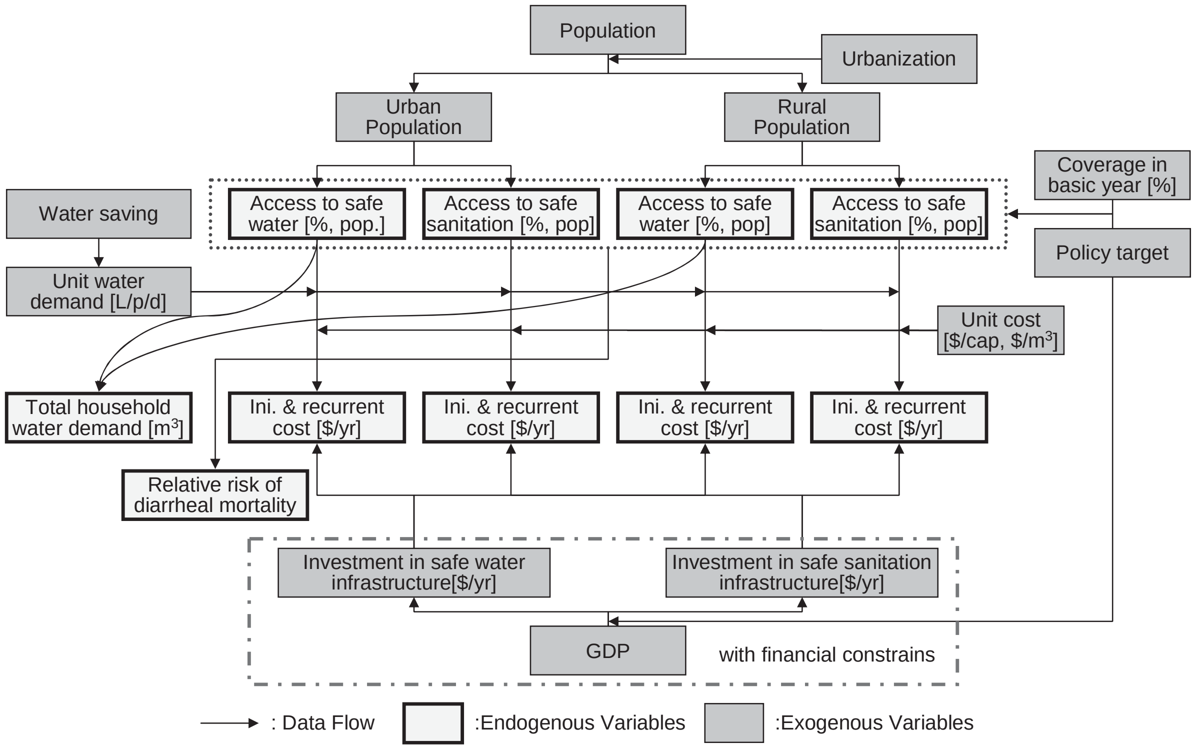


Fig. 5.8.1 WMM Flow chart.

Table 5.8.1 Water supply and sanitation technologies considered to be “improved” and those considered to be “not improved”

The following technologies were considered “improved:”	
Water supply	**Sanitation**
Household connection	Connection to a public sewer
Public standpipe	Connection to septic system
Borehole	Pour-flush latrine
Protected dug well	Simple pit latrine
Protected spring	Ventilated improved pit latrine
Rainwater collection	
The following technologies were considered “not improved:”	
Water supply	**Sanitation**
Unprotected well	Service or bucket latrines (where excreta are manually removed)
Unprotected spring	Public latrines
Vendor-provided water	Open latrine
Bottled water	
Tanker truck provision of water	

5.8.3 Example of Simulation Results

In the MDGs, Target 10 of Goal 7 sets forth the following objective for access to safe water and sanitation - "Halve, by 2015, the proportion of people without sustainable access to safe drinking water and basic sanitation." Moreover, the following target is specified in the VISION 21 report prepared by the Water Supply and Sanitation Collaborative Council (WSSCC) - Target: "By 2025, to provide water, sanitation and hygiene for all." Cases 1 thru 3 are targeted towards safe water supply and sanitation. The scenarios for water and sanitation involve different technologies but the fundamental concept is the same. Cases 1 thru 3 have been set to achieve the MDGs for 2015 and VISION 21 targets for 2025 in all cases. However, different ratios of technology coverage have been set in the respective scenarios.

In Case 1 below, which denotes coverage composition ratios classified by technologies in the base year remain fixed in the future, the composition ratios of safe water and sanitation coverage classified by technologies in the base year are the same in 2015 and 2025.

In Case 2 below, which denotes universal access to the most advanced technology, all people have access to the most advanced technology (household connection and public sewer, in this case) in 2025, when they all have access to safe water and sanitation. From 2000 to 2025, the coverage of household connection and public sewer are assumed to increase linearly.

In Case 3 below, which denotes widespread coverage of the least expensive technology in the future, the situation is set on the assumption that people who newly become able to access safe water from 2000 to 2025 have access to the least expensive technology (Well/Pond/Borehole and VIP/Simple pit latrine). People who can access more expensive technology than wells in the “base year” are assumed to be able to access the same technology until 2025. This means that the population with access to safe water and sanitation supplied by a more expensive technology than wells is set at a fixed level from 2000 to 2025.

The WMM has been applied to India, China and Thailand. Fig. 5.8.2 shows some of the results. For all three countries, the greatest decline in the relative risk of diarrhea mortality, for the timeframe covering the 2000-2025 period, will come when all households are supplied with household connection and have a public sewer connection as well (see Case 2). However, in Case 2, the increase in the annual cost of supplying water and sanitation is the highest. As for Case 3, where water is supplied to new households by cheap options such as wells, ponds, or boreholes and cheap sanitation options are provided, such as ventilated improved pits (VIP) or simple pit latrines, annual costs will be lower but the risk of diarrhea mortality will decline lower than in Case 1, where there is no change in the technology mix of water supply and sanitation systems. Thailand is not expected to witness any decline in diarrhea mortality risk in Case 3. This is because its total access to safe water and sanitation is not likely to increase significantly from 2000 to 2025, and, almost all of its existing households have septic tank systems for treating waste water that have a similar impact on diarrheal mortality as cheaper sanitation options.

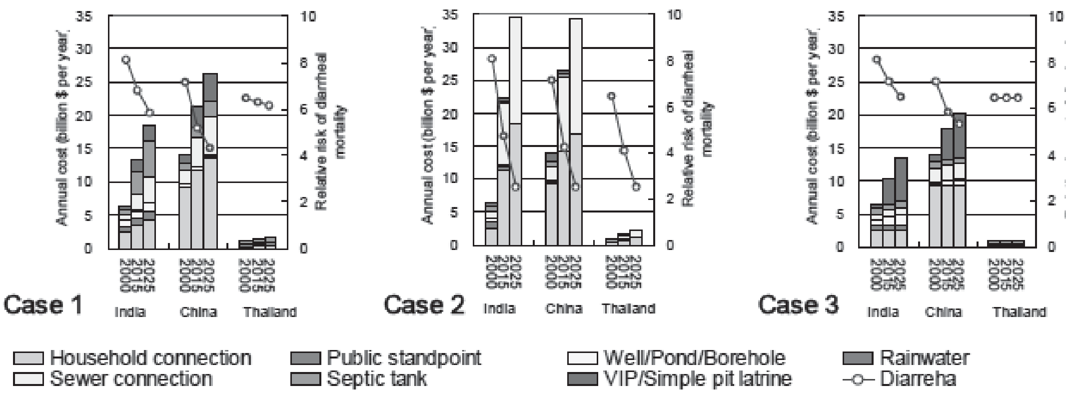


Fig. 5.8.2 Annual cost of water supply and sanitation, and health risk in 2000, 2015, 2025, in India, China, and Thailand represented by the 3 cases below.

5.9 AIM/Enduse (Air) Model

5.9.1 Characteristics of AIM/Enduse (Air)

The purpose of the AIM/Enduse (Air) model is to calculate the diffusion of air pollutants emitted from three sources: 1) emissions from a large point source (LPS) that has a tall stack, such as power plants, boilers, factory reactors, waste incinerators, etc.; 2) an area source (AS) having a lower emission point, such as a factory with a low stack, transporters, houses, fields, etc.; and 3) a line source (LS), such as roads. The AIM/Enduse (Air) model has the following characteristics.

- It allows air quality modeling in the framework of the AIM family
- It supplements the AIM/Enduse model
- SO_2, NOx, are the target pollutants. (SPM is the third target pollutant.)
- It calculates pollutant concentrations for every hour of a specified period.
- It assesses health risks related to energy use by calculating air pollutant concentrations.

5.9.2 Structure of AIM/Enduse (Air) Model

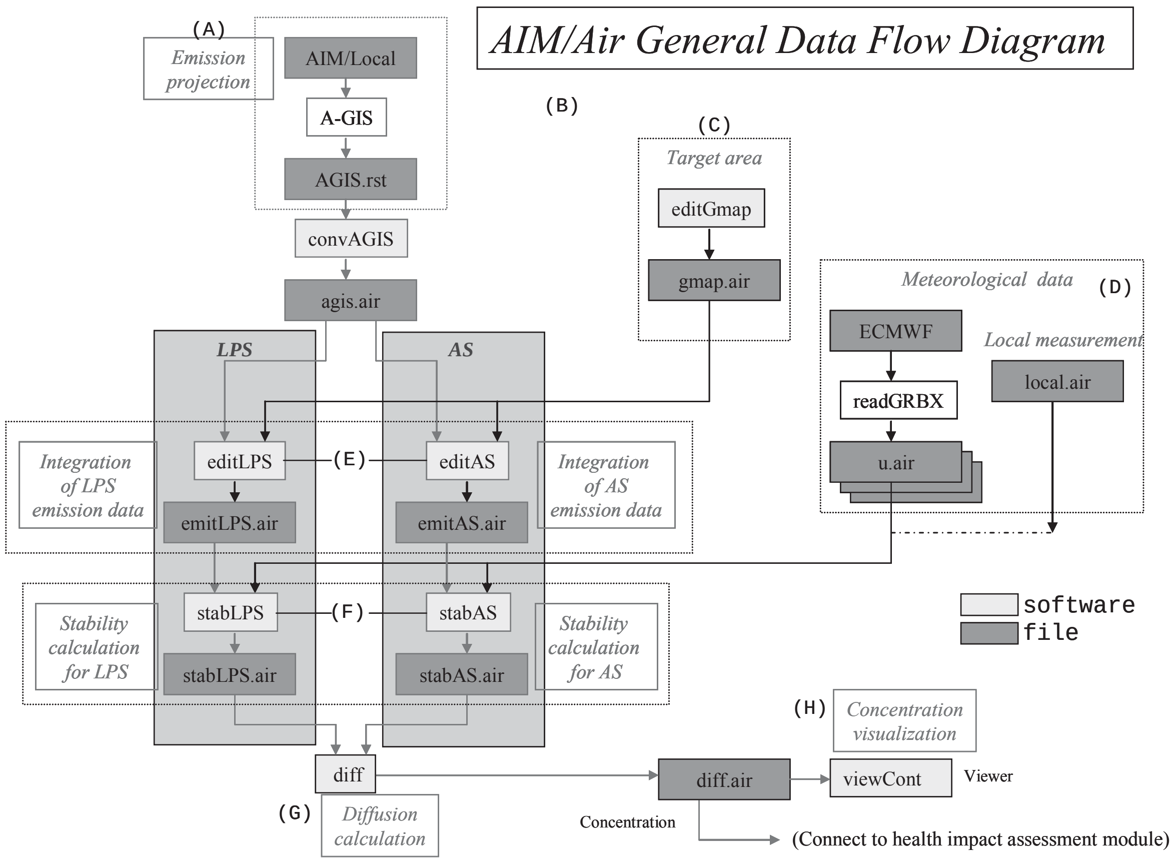


Fig. 5.9.1 AIM/Enduse[Air] Model flow chart.

Outline:

(A) This part is the interface between AIM/Enduse and AIM/Enduse (Air). It converts the pollutant emissions from each district, estimated by AIM/Enduse, into a matrix of emissions data sector by sector using A-GIS (on IDRISI) converter software.

(B) Develop a database of emission patterns representing hourly, daily, and monthly changes in emissions for each sector.

(C) Make a grid map corresponding to the target area. Each cell in the gird is a unit of the area source and also a receptor position for the calculated pollutant concentration.

(D) Delete the meteorology data for the target area from the worldwide meteorology database (the operational analysis data provided by ECMWF) and interpolate and form the data. Other meteorology data, measured by local observation sites, is also available.

(E) Edit large point source (LPS) data. Select an emissions pattern from the defined LPS patterns. Also edit area source (AS) data. Select an emissions pattern for each cell from the defined patterns.

(F) Calculate the index of atmospheric stability for each LPS and each cell of the AS. Calculates the diffusion parameter corresponding to the index

(G) Calculate the concentration distributions of air pollutants based on diffusion equations (plume and puff models).

(H) Visualize the concentration distributions of air pollutants.

Specification of AIM/Enduse (Air) software

- Grid size: fineness of the gird is limited only by CPU power and RAM. For instance, the target area can be 100 km x 100 km with grid cells 1 km x 1 km, or the target area can be 10 km x 100 km with grid cells 100 m x 100 m. The target size and cell size are flexibly adjustable.
- The emissions pattern for LPS data should be designed according to the actual operating schedule for the factory. That of AS cell data should be designed by considering land use, type of industrial area, residential area, roads, agricultural fields, etc.
- Hourly, weekly and monthly changes in emissions intensity can be defined.
- Meteorology data, locally corrected at the observation sites, is available for the diffusion calculation.
- The pollutant concentrations for every hour of the specified period are calculated.
- An effective computational algorithm to calculate plume-type diffusion from AS cells is implemented.
- GUI is available for PC's, and the software runs under both Windows and Linux.

Model description

<u>1) Models of LPS and AS</u>

Plume and puff models are used to calculate air pollutant diffusion from LPS. These two models are conventionally used for diffusion calculations in Japan. The models represent the static distribution of air pollutants under constant conditions of wind direction, wind velocity, solar radiation during the day (or cloud cover at night).

Area source (AS) refers to air pollutants that are homogeneously emitted from the area. The magnitude of the emissions is expressed as the averaged emissions quantity per unit of time and area. Although integral operation of the emissions formula is intrinsically necessary, the numerical integration consumes much computational time. Therefore, AIM/Enduse (Air) regards an area source as an aggregate of small emissions sources. The aggregated fine grid is mapped to parallel the wind flow direction. The distribution from each fine source cell to all normal cells is calculated and the calculated concentrations in each normal cell are summed.

Line source (LS) refers to line of point sources.

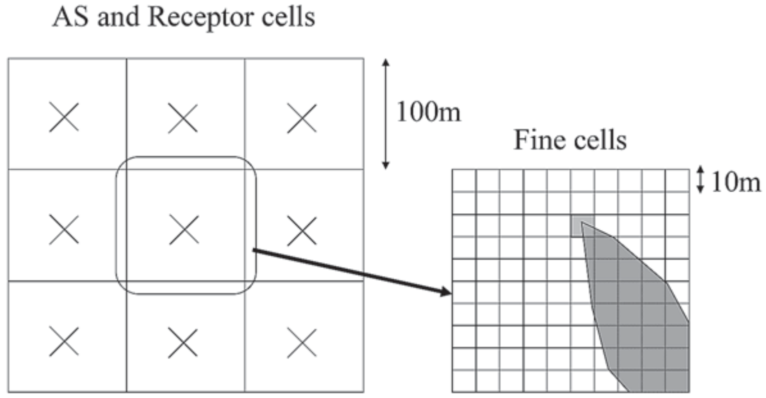


Fig. 5.9.2 Diffusion from area source.

2) Plume model

This diffusion equation is used when the wind velocity is more than 1(m/s). In this case, the concentration of pollutants diffuses horizontally and vertically, similar to a Gaussian distribution, around the x coordinate. The concentration is calculated using the following equation.

$$C(x,y,z)=\frac{Q_P}{2\pi\sigma_y\sigma_z u}\exp\left(-\frac{y^2}{2\sigma_y{}^2}\right)\exp\left\{\left(-\frac{(z-H_e)^2}{2\sigma_z{}^2}\right)+\left(-\frac{(z+H_e)^2}{2\sigma_z{}^2}\right)\right\}$$

x: downstream coordinate, y: horizontally transverse coordinate, z: vertical coordinate (typical height = 1.5 m), Q_p: emissions from point source (kg/year), u: wind velocity (m/s), σ_y, σ_z : diffusion coefficients of coordinates y and z (m), calculated using the following equations

$$\sigma_y=\gamma_y\cdot x^{\alpha_y},\ \sigma_z=\gamma_z\cdot x^{\alpha_z}$$

γ_y, γ_z, α_y, α_z: parameters given by the Pasquill-Gifford diagram. H_e: effective height of stack (m), which is given by the following CONCAWE equation.

$$H_e=H+\Delta H$$

$$\Delta H=0.175Q_H{}^{1/2}u_h{}^{-3/4}$$

$$Q_H=\rho C_p q_g\left(T_g-T_0\right)$$

Q_H: heat emissions (cal/s), u_h wind velocity at the stack's outlet.

The center axis (x coordinate) of the diffusion shape is usually higher than the stack height because the emitted gas is at a high temperature and rises.

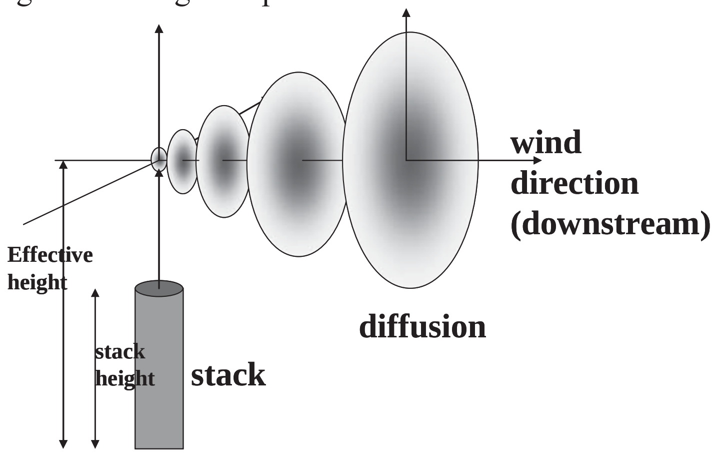


Fig. 5.9.3 Illustrative image of plume diffusion.

3) Puff model

This diffusion model is used when there is no wind or a very weak wind.
The concentration of pollutants is described using the following equation.

$$C(x,y,z)=\frac{Q_P}{(2\pi)^{3/2}\gamma}\exp\left(-\frac{u^2}{2\alpha^2}\right)\left[\frac{1}{\eta_-^2}\left\{1+\frac{\sqrt{\pi/2}\cdot ux}{\alpha\eta_-}\exp\left(\frac{u^2x^2}{2\alpha^2\eta_-^2}\right)\mathrm{erfc}\left(-\frac{ux}{\sqrt{2}\alpha\eta_-}\right)\right\}+\frac{1}{\eta_+^2}\left\{1+\frac{\sqrt{\pi/2}\cdot ux}{\alpha\eta_+}\exp\left(\frac{u^2x^2}{2\alpha^2\eta_-^2}\right)\mathrm{erfc}\left(-\frac{ux}{\sqrt{2}\alpha\eta_+}\right)\right\}\right]$$

$$\eta_-^2=x^2+y^2+\frac{\alpha^2}{\gamma^2}(z-H_e)^2$$

$$\eta_+^2=x^2+y^2+\frac{\alpha^2}{\gamma^2}(z+H_e)^2$$

$$\mathrm{erfc}(W)=\frac{1}{\sqrt{\pi}}\int_W^\infty e^{-t^2}\,dt$$

where α and γ is given with Pasquill stability classification. In this case, the differential height ΔH in the *He* is given by Briggs equation. The erfc(W) refers to the error function.

$$\Delta H=1.4Q_H^{1/4}\left(\frac{d\theta}{dz}\right)^{-3/8}$$

dθ/dz is the potential temperature gradient (K/m)

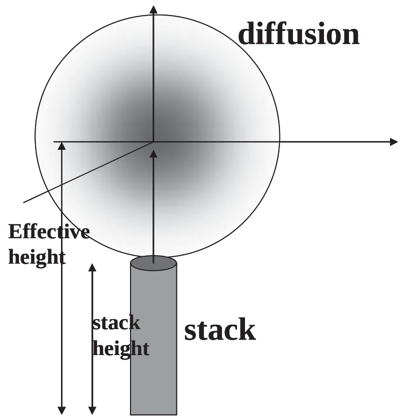


Fig. 5.9.4 Illustration of puff diffusion.

4) Required data

The data required for AIM/Enduse (Air) is listed in the following table.

Table 5.9.1 Data required for AIM/Enduse (Air)

Emissions quantity	Annual quantity (kg/year), sector by sector, output from Enduse model.
Emission pattern	Daily, weekly, and monthly changes in emissions, sector by sector
LPS	Location (latitude and longitude), stack height, gas (flow, temperature, specific heat)
AS	Land-use map, emissions height, gas (flow, temperature, specific heat)
LS	Road map, traffic volume by transporter-type, emissions factor (kg/m) by transporter-type
Meteorological data	Wind direction and velocity, air temperature, solar radiation, cloud cover

5.9.3 Application to China

Using AIM/Local (Enduse), the SO_2 emissions in Beijing were calculated for iron & steel, nonferrous metals, cement, power, transport, commerce, and public sectors. Using the land-use map shown in Fig. 5.9.5, emissions from each sector were disaggregated into the related land-use area. For instance, emissions from the public sector were disaggregated into residential areas on the grid map (Fig. 5.9.6). Emissions from the industrial sector, commercial sector, and traffic sector were disaggregated into industrial areas, public building areas, and roads, respectively. The SO_2 concentration at each hour was calculated using AIM/Enduse (Air) models. The daily mean concentration and contribution from each sector are plotted in Fig. 5.9.7. This figure shows SO_2 emissions are highest during the winter, and the largest ratio of contribution is from the commercial sector. This is one reason why heating in commercial areas uses so much energy in the winter.

The combination of AIM/Enduse and AIM/Enduse (Air) is a powerful tool for analyzing the influence of energy policy on air pollution.

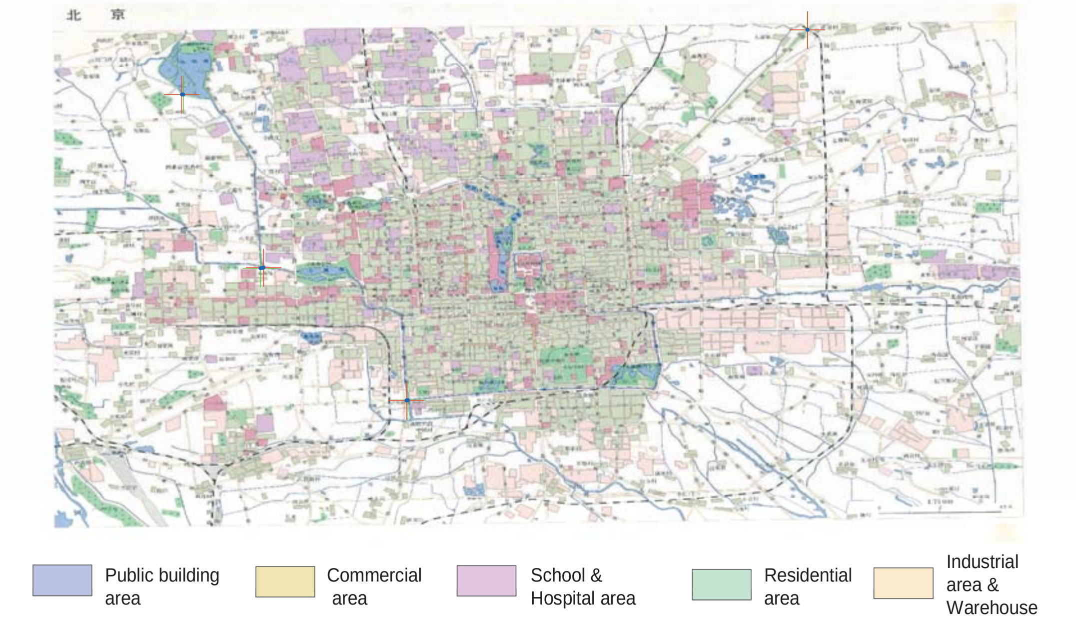


Fig. 5.9.5 Land-use information for Beijing city.

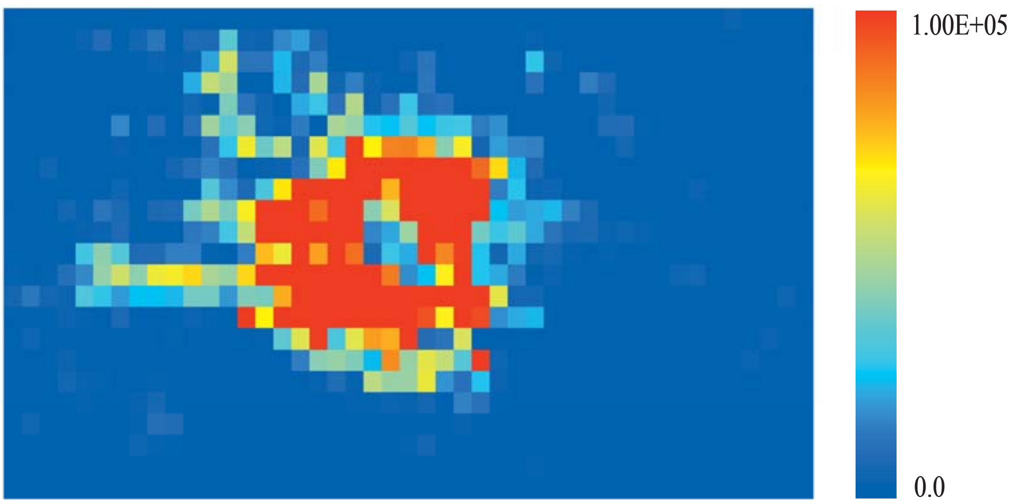


Fig. 5.9.6 Emissions from residential areas (grid map data; kg/year/cell).

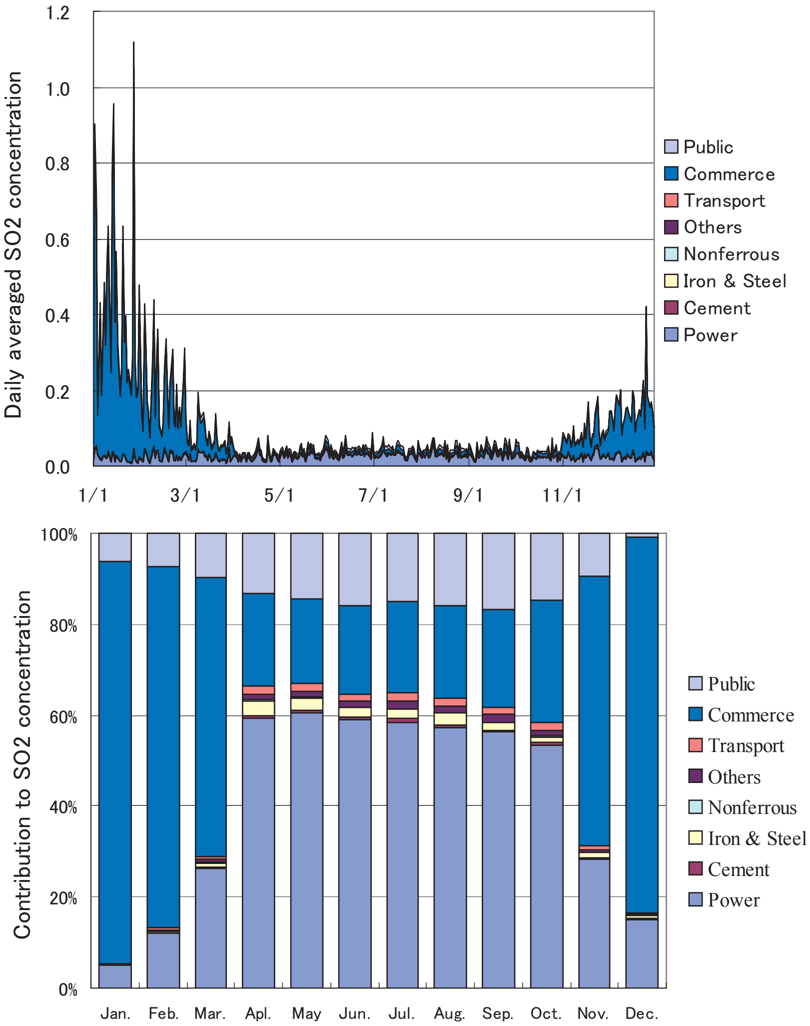


Fig. 5.9.7 Daily mean SO_2 concentration in Beijing and contributions from various sectors in 2000.

PART Ⅱ

Energy Snapshot Tool (ESS)

Manual

1. What is ESS?

1.1 Characteristics of ESS

The Energy SnapShot tool (ESS) is developed on the spreadsheet as shown in Fig.1.1. Giving service demand, share of energy and energy improvement by classification of service and energy in the base year and the target year, the tool calculates the energy balance table and the CO_2 emission table immediately with keeping consistency among sectors.

Since users can conduct sensitivity analysis with different parameters promptly, the model is suitable for the communication among stakeholders to design low carbon society. Besides, the model can be used as a simple assessment tool of output from various models.

Residential sector

1 Energy service demand

	Unit	2000	2050					
			REF		CM		CM/REF	
			A	B	A	B	A	B
Cool	Mtoe	3	5	3	4	3	90%	90%
Warm	Mtoe	17	15	13	10	9	67%	67%
Hot Water	Mtoe	11	7	12	6	9	80%	80%
Cooking (S)	Mtoe	1	1	1	1	1	100%	100%
Cooking (E)	Mtoe	1	1	1	1	1	100%	100%
Lighting	Mtoe	3	5	3	4	3	80%	80%
Refrigerator	Mtoe	4	3	3	3	3	100%	100%
ICT	Mtoe	2	3	2	3	2	100%	100%
Appliance	Mtoe	10	13	10	13	10	100%	100%
					0	0		
					0	0		

REF = Reference case
CM = Countermeasure case

4-6 Energy consumption / CO2 Emission

		Unit	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
4 Energy Consumption	2000	Mtoe	0	21	9	0	1	0	0	23	54
	2050 A (CM)		0	1	1	0	8	0	4	14	28
	2050 B (CM)		0	2	2	7	18	0	0	8	37
5 Emission Factor	2000	MtC/Mtoe	1.05	0.80	0.55	0.00	0.00	0.00	0.00	1.19	-
	2050 A (CM)		1.05	0.80	0.55	0.00	0.00	0.00	0.52	0.28	-
	2050 B (CM)		1.05	0.80	0.55	0.00	0.00	0.00	0.00	0.63	-
6 CO2 Emission	2000	MtC	0	16	5	0	0	0	0	27	49
	2050 A (CM)		0	1	0	0	0	0	2	4	7
	2050 B (CM)		0	1	1	0	0	0	0	5	7

2 Service Share

	Unit	2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Warm	-	0%	59%	15%	0%	0%	0%	0%	26%	100%
Hot Water	-	0%	55%	33%	0%	7%	0%	0%	5%	100%
Cooking (S)	-	0%	44%	56%	0%	0%	0%	0%	0%	100%
Cooking (E)	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Lighting	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Refrigerator	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
ICT	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
Appliance	-	0%	0%	0%	0%	0%	0%	0%	100%	100%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%

	2050 A (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								100%	100%
Warm		5%	5%			10%		80%	100%
Hot Water		5%	5%		10%	10%		70%	100%
Cooking (S)		5%	5%					90%	100%
Cooking (E)								100%	100%
Lighting								100%	100%
Refrigerator								100%	100%
ICT								100%	100%
Appliance								100%	100%
									0%
									0%

	2050 B (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								100%	100%
Warm		5%	5%	50%				40%	100%
Hot Water		10%	10%	20%	30%			30%	100%
Cooking (S)		15%	20%	35%				30%	100%
Cooking (E)								100%	100%
Lighting								100%	100%
Refrigerator								100%	100%
ICT								100%	100%
Appliance								100%	100%
									0%
									0%

3 Energy efficiency

	Unit	2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	toe/toe								2.84	-
Warm	toe/toe		0.90	0.90	0.90				3.69	-
Hot Water	toe/toe		0.75	0.75	0.75	1.00			0.62	-
Cooking (S)	toe/toe		0.45	0.45	0.45	0.45			0.70	-
Cooking (E)	toe/toe								1.00	-
Lighting	toe/toe								1.00	-
Refrigerator	toe/toe								1.00	-
ICT	toe/toe								1.00	-
Appliance	toe/toe								1.00	-
										-
										-

	2050 A (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								8.00	-
Warm		0.90	0.90	0.90		1.00		8.00	-
Hot Water		0.95	0.95	0.95	0.95	1.00		6.00	-
Cooking (S)		0.55	0.55	0.55	0.55			0.80	-
Cooking (E)								1.11	-
Lighting								1.50	-
Refrigerator								1.50	-
ICT								2.00	-
Appliance								1.50	-
									-
									-

	2050 B (CM)								
	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								8.00	-
Warm		0.90	0.90	0.90		1.00		8.00	-
Hot Water		0.95	0.95	0.95	0.95	1.00		6.00	-
Cooking (S)		0.55	0.55	0.55	0.55		0.55	0.80	-
Cooking (E)								1.11	-
Lighting								1.50	-
Refrigerator								1.50	-
ICT								2.00	-
Appliance								1.50	-
									-
									-

Fig.1.1 ESS. (partly, Residential sector).

1.2 Structure of ESS

ESS is comprised of the worksheets as shown in Table1.1. The relationship among the worksheets is shown in Fig.1.2.

Table1.1 Worksheets of ESS

Worksheet	Content
Title	Cover of ESS
CTL	Enter unit, simulation year, scenario name and CO_2 emission factor
IND	Develop energy flow in industrial sector
RES	Develop energy flow in residential sector
COM	Develop energy flow in commercial sector
TR_P	Develop energy flow in passenger transportation sector
TR_F	Develop energy flow in freight transportation sector
PWR	Develop energy flow in power generation sector
TTL_SD	Develop energy balance table in both energy enduse sector and energy transformation sector.
TTL_S	Develop energy balance table with countermeasures in energy enduse sector for factors analysis of CO_2 reduction.
TTL_D	Develop energy balance table with countermeasures in energy transformation sector for factors analysis of CO_2 reduction.
TTL_0	Develop energy balance table without countermeasure in both energy enduse sector and energy transformation sector for factors analysis of CO_2 reduction.
Factors	Factors analysis of CO_2 reduction is shown.
EneEms	Graphs of energy consumption and CO_2 emission are shown.

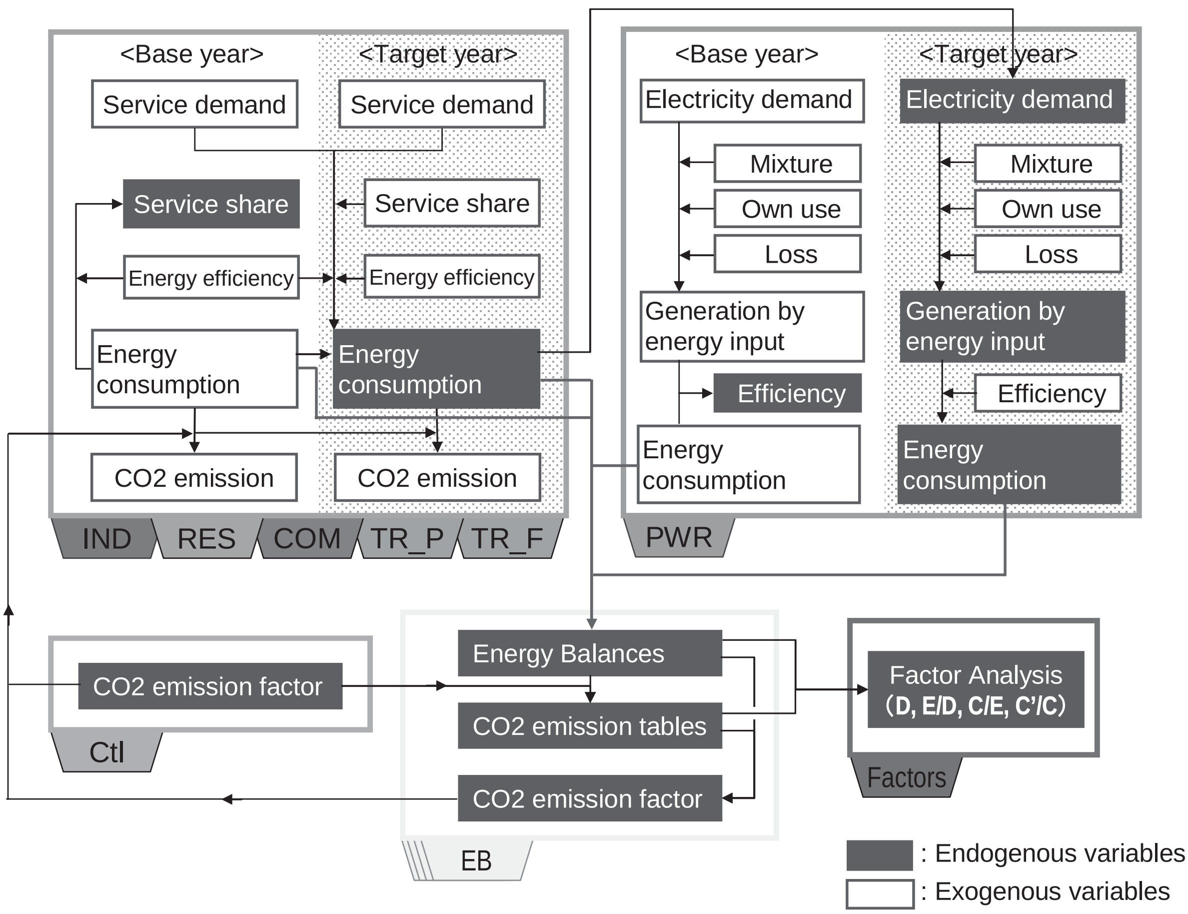


Fig.1.2 Relationship among the worksheet in ESS.

1.3 ESS Software

1.3.1 System requirement

MS Excel must be installed in your PC for execution of ESS.

1.3.2 ESS Software

(ESS can be downloaded from the following website.)not yet
http://2050.nies.go.jp
The ZIP file includes the following files.

- ESS_JPN.xls : Energy balance in Japan

2. How to use ESS

This chapter shows the procedure of entering data on each worksheet.
Users enter values in white cells for development of energy balances and CO_2 emission table. The values in colored cells are shown automatically.

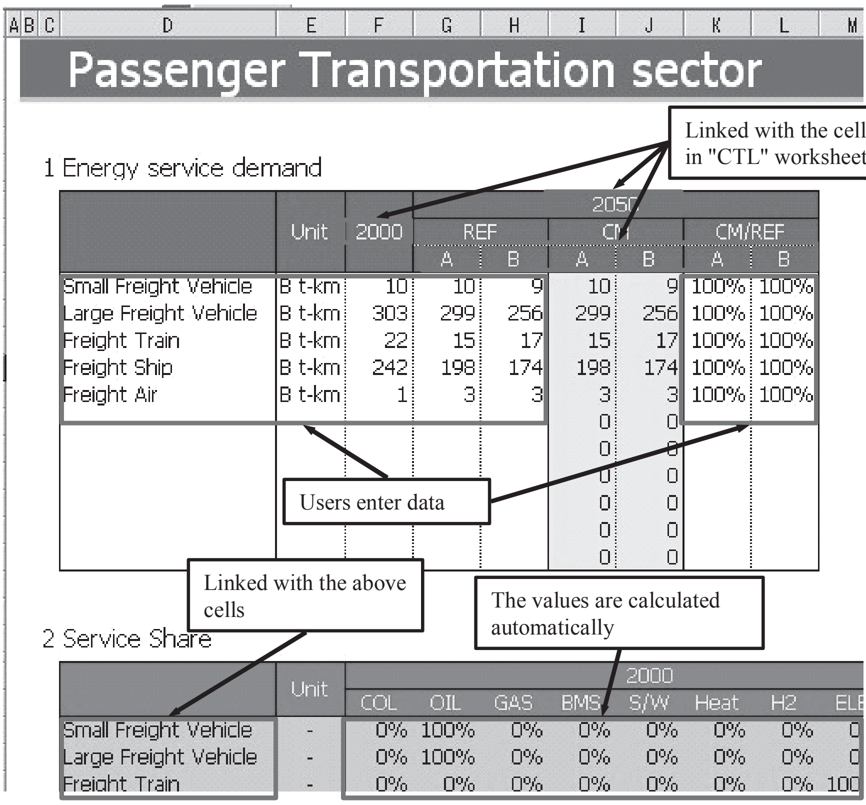


Fig. 2.1 White cell and colored cell.

2.1 CTL

Enter the cell of the following items in the “CTL” worksheet.

- Unit: Energy, CO_2
- Simulation year: Base year, Target year
- Scenario name: Scenario 1, Scenario 2
- Emission Factor: COL, OIL, GAS, BMS, NUC, HYD, S/W

COL = Coal and coal products
OIL = Crude oil and oil products
GAS = Natural gas
BMS = Biomass
NUC = Nuclear
HYD = Hydro
S/W = Solar, Wind, Tide

2.2 IND, RES, COM, TR_P, TR_F

Energy consumption and CO_2 emission in energy enduse sectors are calculated in these worksheets. The “IND” worksheet corresponds to industrial sector, “RES” residential sector, “COM” commercial sector, “TR_P” passenger transportation sector, “TR_F” freight transportation sector. The structures in the worksheets are same. The explanation of each table in the worksheet is shown as follows.

1. Energy service demand

Enter service demand in the base year and the target year in the table. The year and the name of scenarios are shown automatically with linkage of input in the "CTL" worksheet.

1 Energy service demand

	Unit	2000	2050					
			REF		CM		CM/REF	
			A	B	A	B	A	B
Cool	Mtoe	3	5	3	4	3	90%	90%
Warm	Mtoe	17	15	13	10	9	67%	67%
Hot Water	Mtoe	11	7	12	6	9	80%	80%
Cooking (S)	Mtoe	1	1	1	1	1	100%	100%
Cooking (E)	Mtoe	1	1	1	1	1	100%	100%
Lighting	Mtoe	3	5	3	4	3	80%	80%
Refrigerator	Mtoe	4	3	3	3	3	100%	100%
ICT	Mtoe	2	3	2	3	2	100%	100%
Appliance	Mtoe	10	13	10	13	10	100%	100%
					0	0		
					0	0		

Fig. 2.2 "Energy service demand" table in ESS.

Table 2.1 Contents of "Energy service demand" table

Column	Contents
D	Type of energy service. After entering
E	Unit of energy service demand
F	Energy service demand in the base year
G, H	Energy service demand of reference case in a target year. The reference case does not consider effects of measure that decreases the demand.
I*, J*	Energy service demand of countermeasure case in a target year. The countermeasure case does not consider effects of measure that decreases the demand. = G*K, = H*L
K, L	Ratio of service demand of the countermeasure case to that of the reference case.

*: The data in the column is shown automatically.

2. Service share

Enter service share in target year in the table. The service share in the base year is calculated based on the following formulation.

$$SS(s,e) = \frac{EC(s,e) \times EE(s,e)}{\sum_{e} EC(s,e) \times EE(s,e)}$$

SS: Service share
EC: Energy consumption
EE: Energy efficiency
s: Service, *e*: Energy

2 Service Share

	Unit	2000									2050 A (CM)									2050 B (CM)								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	-	0%	0%	0%	0%	0%	0%	0%	100%	100%								100%	100%								100%	100%
Warm	-	0%	59%	15%	0%	0%	0%	0%	26%	100%		5%	5%			10%		80%	100%		5%	5%	50%				40%	100%
Hot Water	-	0%	55%	33%	0%	7%	0%	0%	5%	100%		5%	5%		10%	10%		70%	100%		10%	10%	20%	30%			30%	100%
Cooking (S)	-	0%	44%	56%	0%	0%	0%	0%	0%	100%		5%	5%					90%	100%		15%	20%	35%				30%	100%
Cooking (E)	-	0%	0%	0%	0%	0%	0%	0%	100%	100%								100%	100%								100%	100%
Lighting	-	0%	0%	0%	0%	0%	0%	0%	100%	100%								100%	100%								100%	100%
Refrigerator	-	0%	0%	0%	0%	0%	0%	0%	100%	100%								100%	100%								100%	100%
ICT	-	0%	0%	0%	0%	0%	0%	0%	100%	100%								100%	100%								100%	100%
Appliance	-	0%	0%	0%	0%	0%	0%	0%	100%	100%								100%	100%								100%	100%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%									0%									0%
	-	0%	0%	0%	0%	0%	0%	0%	0%	0%									0%									0%

Fig. 2.3 “Service share” table in ESS.

Table 2.2 Contents of “Service share” table

Column	Contents
D*	Type of energy service.
F* ~ N*	Service share in the base year.
O ~ W	Service share of scenario 1 in the target year.
X ~ AF	Service share of scenario 2 in the target year.

*: The data in the column is shown automatically.

3. Energy efficiency

Energy efficiency is the ratio of service output to energy input. Enter energy use efficiency in base year and target year in the table.

3 Energy efficiency

	Unit	2000									2050 A (CM)									2050 B (CM)								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	toe/toe								2.84	-								8.00	-								8.00	-
Warm	toe/toe		0.90	0.90	0.90				3.69	-		0.90	0.90	0.90		1.00		8.00	-		0.90	0.90	0.90		1.00		8.00	-
Hot Water	toe/toe		0.75	0.75	0.75	1.00			0.62	-		0.95	0.95	0.95	0.95	1.00		6.00	-		0.95	0.95	0.95	0.95	1.00		6.00	-
Cooking (S)	toe/toe		0.45	0.45	0.45	0.45			0.70	-		0.55	0.55	0.55	0.55			0.80	-		0.55	0.55	0.55	0.55		0.55	0.80	-
Cooking (E)	toe/toe								1.00	-								1.11	-								1.11	-
Lighting	toe/toe								1.00	-								1.50	-								1.50	-
Refrigerator	toe/toe								1.00	-								1.50	-								1.50	-
ICT	toe/toe								1.00	-								2.00	-								2.00	-
Appliance	toe/toe								1.00	-								1.50	-								1.50	-
										-									-									-
										-									-									-

Fig. 2.4 “Energy efficiency” table in ESS.

Table 2.3 Contents of “Energy efficiency” table

Column	Contents
D*	Type of energy service.
E	Unit of energy use efficiency
F ~ M	Energy use efficiency in the base year.
O ~ V	Energy use efficiency of scenario 1 in the target year.
X ~ AE	Energy use efficiency of scenario 2 in the target year.

*: The data in the column is shown automatically.

Table 2.4 Example of unit of energy use efficiency (Japan case)

Sector		Unit
Residential & Commercial	Cool, Warm – Heat pump	Coefficient of performance
Residential & Commercial	Warm, Cooking - Stove	Heat efficiency
Residential & Commercial	Others	2000’s efficiency = 1.00
Industrial		2000’s efficiency = 1.00
Transportation		2000’s efficiency = 1.00

4. Energy consumption

Enter energy consumption in base year in the table. The energy consumption in the target year is calculated based on the following formulation.

$$EC(s,e) = \left(\sum_e EC_0(s,e) \times EE_0(s,e) \right) \times \frac{S(s)}{S_0(s)} \times SS(s,e) \div EE(s,e)$$

SS: Service share
EC: Energy consumption
EE: Energy efficiency
$*_0$: Base year
s: Service, *e*: Energy

Users enter energy transformation in each sector in the lower part of the table. Energy flow of electricity and heat generation by photovoltaic and cogeneration is shown here. Energy input is entered with (+), energy output is entered with (-).

4 Energy consumption

		2000								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2
Warm	Mtoe	0.0	10.9	2.8	0.0	0.0	0.0	0.0	1.2	14.9
Hot Water	Mtoe	0.0	8.4	5.0	0.0	0.8	0.0	0.0	1.0	15.2
Cooking (S)	Mtoe	0.0	1.2	1.6	0.0	0.0	0.0	0.0	0.0	2.8
Cooking (E)	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8
Lighting	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.4	3.4
Refrigerator	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	3.6
ICT	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	2.1
Appliance	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.9	9.9
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Generation	Mtoe									0.0
Cogeneration	Mtoe									0.0
	Mtoe									0.0
Total	Mtoe	0	21	9	0	1	0	0	23	54

		2050 A (CM)								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5
Warm	Mtoe	0.0	0.5	0.5	0.0	0.0	1.0	0.0	1.0	3.1
Hot Water	Mtoe	0.0	0.3	0.3	0.0	0.6	0.6	0.0	0.7	2.4
Cooking (S)	Mtoe	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.7	0.8
Cooking (E)	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.8
Lighting	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	2.5
Refrigerator	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2
ICT	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.5
Appliance	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.9	8.9
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Generation	Mtoe					7.6			-2.9	4.7
Cogeneration	Mtoe						-1.6	3.9	-1.7	0.6
	Mtoe									0.0
Total	Mtoe	0	1	1	0	8	0	4	14	28

		2050 B (CM)								
		COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3
Warm	Mtoe	0.0	0.5	0.5	4.9	0.0	0.0	0.0	0.4	6.3
Hot Water	Mtoe	0.0	1.0	1.0	2.0	2.9	0.0	0.0	0.5	7.3
Cooking (S)	Mtoe	0.0	0.2	0.3	0.5	0.0	0.0	0.0	0.3	1.4
Cooking (E)	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.6
Lighting	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.8
Refrigerator	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	2.2
ICT	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0
Appliance	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	6.5
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Mtoe	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Generation	Mtoe					16			-6	9.6
Cogeneration	Mtoe						0.0	0.0	0	0.0
	Mtoe									0.0
Total	Mtoe	0	2	2	7	18	0	0	8	37

Fig. 2.5 "Energy consumption" table in ESS.

5. Emission Factor

The emission factors are shown automatically. The factors of coal, oil, gas, biomass are linked with the value in the "CTL" sheet. The factors of electricity and hydrogen are linked with the value in the "TTL_SD" sheet.

6. CO_2 Emission

The CO_2 emissions in the base year and the target year are shown automatically. The CO_2 emissions are calculated based on the following formulation.

$$CO2(e) = EC(e) \times EF(e)$$

CO_2: CO_2 emission
EC: Energy consumption
EF: CO_2 emission factor
e: Energy

4-6 Energy consumption / CO2 Emission

		Unit	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
4 Energy Consumption	2000	Mtoe	0	21	9	0	1	0	0	23	54
	2050 A (CM)		0	1	1	0	8	0	4	14	28
	2050 B (CM)		0	2	2	7	18	0	0	8	37
5 Emission Factor	2000	MtC/Mtoe	1.05	0.80	0.55	0.00	0.00	0.00	0.00	1.19	-
	2050 A (CM)		1.05	0.80	0.55	0.00	0.00	0.00	0.52	0.28	-
	2050 B (CM)		1.05	0.80	0.55	0.00	0.00	0.00	0.00	0.63	-
6 CO2 Emission	2000	MtC	0	16	5	0	0	0	0	27	49
	2050 A (CM)		0	1	0	0	0	0	2	4	7
	2050 B (CM)		0	1	1	0	0	0	0	5	7

Fig. 2.6 "Energy consumption", "Emission factor", "CO_2 emission" table in ESS.

2.3 PWR

This sheet calculates electricity generation and energy consumption in power generation sector under the condition that electricity demand in enduse sector is equal to electricity supply in power generation sector. The solver can match electricity demand and supply automatically. The tables in a target year are four types as follows.

- Supply and demand: Considering countermeasures in both enduse sector and energy transformation sector.
- Only demand: Considering countermeasures in only enduse sector.
- Only Supply : Considering countermeasures in only energy transformation sector.
- No : Considering no countermeasures.

"Only demand", "Only demand", "No" table is for factor analysis of CO_2 reduction. The data in the three table is calculated automatically.

The explanation of each table is shown as follows.

1. Electricity demand at receiver end

Total electricity demand of all the sectors. Enter the value in the base year. The value in a target year is linked with the summation of electricity consumption in the summarized sheet (TTL_SD, TTL_D, TTL_S, TTL_0).

2. Difference between demand and supply

Difference between electricity demand at receiver end (10^{th} line) and electricity supply (18^{th} line). The solver whose command button is located at [5,F] decides electricity supply under the condition that the difference is zero. If the value in this table is not zero, click the solver button.

3. Electricity supply at receiver end

3-1. Electricity supply

Electricity supply at receiver end. The values are shown based on the following formulation.

Electricity supply at receiver end

= Electricity supply before transmission (4-1) x (1-Tranmission loss(3-2))

3-2. Transmission loss

Transmission loss factor between electricity supplier and receiver. Enter the value in a base year and a target year.

Power generation sector

Solver

			2050							
		2000	Supply & Demand		Only Demand		Only Supply		No	
			A	B	A	B	A	B	A	B
1. Electricity demand at receiver end										
	Mtoe	72	62	44	62	44	88	71	88	71
2. Difference between demand and supply										
	Mtoe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3. Electricity supply at receiver end										
Electricity supply	Mtoe	72	62	44	62	44	88	71	88	71
Transmission Loss		5.31%	5.31%	5.31%	5.3%	5.3%	5.3%	5.3%	5.3%	5.3%
4. Electricity supply before tranmission										
Electricity supply	Mtoe	76	65	46	65	46	93	75	93	75
Pumped storage (PS)										
Ele. demand of PS	Mtoe	1	1.08	1	1	1	2	1	2	1
Efficiency		84.7%	84.7%	84.7%	84.7%	84.7%	84.7%	84.7%	84.7%	84.7%
Generation of PS	Mtoe	1	1	1	1	1	1	1	1	1
Own use										
Own use in plant	Mtoe	3	3	2	3	2	4	3	4	3
Own use rate										
COL		6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%	6.0%
OIL		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
GAS		4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%	4.0%
NUC		4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%	4.4%
HYD		0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
HYD(P)		0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
GEO		8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
BMS		5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
S/W		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5. Electricity supply at generation end										
Electricity supply										
Total	Mtoe	81	69	49	70	49	98	79	99	79
COL	Mtoe	15	9	2	13	9	12	4	18	15
OIL	Mtoe	9	3	2	7	5	5	4	11	8
GAS	Mtoe	21	20	18	18	13	29	30	26	21
NUC	Mtoe	28	28	12	24	17	39	20	34	27
HYD	Mtoe	7	8	8	6	4	11	13	8	7
HYD(P)	Mtoe	1	0.92	1	1	1	1	1	1	1
GEO	Mtoe	0	0	0	0	0	0	0	0	0
BMS	Mtoe	0	0	5	0	0	0	8	0	0
S/W	Mtoe	0	0	0	0	0	0	0	0	0
Share of electricity supply										
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%
COL		18%	12%	5%	18%	18%	12%	5%	18%	18%
GAS		11%	5%	5%	11%	11%	5%	5%	11%	11%
OIL		26%	29%	38%	26%	26%	29%	38%	26%	26%
NUC		34%	40%	25%	34%	34%	40%	25%	34%	34%
HYD		8%	11%	16%	8%	8%	11%	16%	8%	8%
HYD(P)		1%	1%	1%	1%	1%	1%	1%	1%	1%
GEO		0%	0%	1%	0%	0%	0%	1%	0%	0%
BMS		0%	0%	10%	0%	0%	0%	10%	0%	0%
S/W		0%	0%	0%	0%	0%	0%	0%	0%	0%
6. Thermal Efficiency										
COL		40.1%	48.0%	48.0%	40.1%	40.1%	48.0%	48.0%	40.1%	40.1%
OIL		37.0%	40.0%	40.0%	37.0%	37.0%	40.0%	40.0%	37.0%	37.0%
GAS		42.2%	55.0%	55.0%	42.2%	42.2%	55.0%	55.0%	42.2%	42.2%
BMS		33.0%	40.0%	40.0%	33.0%	33.0%	40.0%	40.0%	33.0%	33.0%
7. Primary Energy Consumption										
COL	Mtoe	37	18	5	32	23	26	8	45	36
OIL	Mtoe	23	9	6	20	14	12	9	28	23
GAS	Mtoe	51	37	33	43	31	52	54	62	50
NUC	Mtoe	84	84	37	72	51	119	60	102	82
HYD	Mtoe	7	8	8	6	4	11	13	8	6
GEO	Mtoe	3	3	3	2	2	4	5	3	3
BMS	Mtoe	92	69	31	72	51	98	49	102	82
S/W	Mtoe	0	0	5	0	0	0	8	0	0

Conversion factor from secondary to primary : NUC = 1/33%, HYD = 1, GEO = 1/10%, S/W = 1

Fig. 2.7 PWS worksheet.

4. Electricity supply before transmission

4-1. Electricity supply

Electricity supply at before transmission. The values are calculated based on the following formulation.

Electricity supply before transmission

= Electricity supply at generation end (5-1)

– Electricity demand of pumped storage(4-2-1) – Own use in plant(4-3-1)

4-2. Pumped storage

4-2-1. Electricity demand of PS

Electricity demand of pumped storage. The values are calculated based on the following formulation.

Electricity demand of pumped storage
= Electricity generation of pumped storage(4-2-3) / Efficiency(4-2-)

4-2-2. Efficiency

Generation efficiency of pumped storage. Enter the value in the base year and the target year.

4-2-3. Generation of PS

Electricity generation of pumped storage. The values are shown based on the following formulation.

Electricity generation of pumped storage
= Electricity supply of pumped storage at generation end(5-1) / (1-Own use rate (4-3))

4-3. Own use

4-3-1. Own use in plant

Electricity consumption for own use in plant. The values are calculated based on the following formulation.

*Own use in plant = Electricity supply(5-1) * Own use rate(4-3-2)*

4-3-2. Own use rate

Electricity consumption for own use in plant. The values are shown based on the following formulation. Enter the value in the base year and the target year.

5. Electricity supply at generation end

5-1. Electricity supply

Electricity supply (=generation) at generation end. The solver calculates the total values. Enter the value of each generation type in a base year. The values of a target year are calculated based on the following formulation.

*Electricity supply = Electricity supply (Total) * Share of electricity supply (5-2)*

5-2. Share of electricity supply

Share of electricity supply by energy input. Enter the value of each generation type in a target year. The values of a base year are calculated based on the following formulation.

Share of electricity supply
= Electricity supply by energy input(5-1) / Total electricity supply

6. Thermal efficiency

Ratio of electricity generation to energy input. Enter the value in a target year. The values of a base year are calculated based on the following formulation.

Thermal efficiency = Electricity generation (5-1) / Energy consumption (7)

7. Primary energy consumption

Primary energy consumption for ratio of electricity generation to energy input. Enter the values in a base year. The values of a target year are calculated based on the following formulation.

Primary energy consumption = Electricity generation (5) / Thermal efficiency (6)

2.4 EB_SD, EB_D, EB_S, EB_0

Energy balance table is developed in “EB_SD”, “EB_D”, “EB_S”, “EB_0”.

- EB_SD: Energy balances considering countermeasures in both enduse sector and energy transformation sector.
- EB_D: Energy balances Considering countermeasures in only enduse sector.
- EB_S: Energy balances Considering countermeasures in only energy transformation sector.
- EB_0 : Energy balances Considering no countermeasures.

“EB_D”, “EB_S”, “EB_0” table is for factor analysis of CO_2 reduction.

The explanation of each table is shown as follows.

1. CO_2 emission in 1990

[Line 7, Column F-P]

Enter CO_2 emission in 1990. The value is used for calculation of the emission ratio to the 1990’s emission.

2. Energy balances

・Power Gnr.

[Line 12, Column F-P]: Base year
[Line 33, Column F-P]: Scenario 1, Target year
[Line 54, Column F-P]: Scenario 2, Target year

Energy flow of power generation in a base year. Energy consumptions and electricity generation in power generation is shown automatically. The values are linked with energy consumption and electricity generation in PWR.

・CCS, Heat, Coal/Oil/Gas, Hydrogen

[Line 13-16, Column F-P]: Base year
[Line 34-37, Column F-P]: Scenario 1, Target year
[Line 55-58, Column F-P]: Scenario 2, Target year

Energy flow of carbon capture storage, heat plant, production of coal products, oil refinery, gas works and production of hydrogen in a base year.

Enter energy flow in each sector. Energy input is entered with (+), energy output is entered with (-).

・Industrial, Residential, Commercial, Trans. Prs., Trans. Frg.

[Line 17-22, Column F-P]: Base year
[Line 38-43, Column F-P]: Scenario 1, Target year
[Line 59-64, Column F-P]: Scenario 2, Target year

Energy flow of industrial, residential, commercial, passenger transportation and freight transportation sectors in a base year. Energy consumptions and electricity generation in power generation is shown automatically. The values are linked with energy consumption in IND, RES, COM, TR-P and TR-F.

・Total
[Line 23, Column F-P]: Base year
[Line 44, Column F-P]: Scenario 1, Target year
[Line 65, Column F-P]: Scenario 2, Target year
Primary energy consumption. The value is summation of energy input and output of all the sectors.

・Feedstocks in total
[Line 24, Column F-P]: Base year
[Line 45, Column F-P]: Scenario 1, Target year
[Line 66, Column F-P]: Scenario 2, Target year
Feedstocks in total energy consumption. Feedstocks cover energy consumption for products for non-energy use. CO_2 emission is calculated from energy consumption not including feedstocks. Enter feedstocks by energy input.

3. Emission factor
[Line 25]: Base year
[Line 46]: Scenario 1, Target year
[Line 67]: Scenario 2, Target year
CO_2 emission factors are shown automatically. Emission factors of COL, OIL, GAS, BMS, NUC, HYD, S/W is linked with the value in the “CTL” sheet. Emission factors of Heat, H2 and ELE are calculated by the following formulation.

$$EF("Heat") = \sum_e EC("Heat", e) * EF(e) / Heat$$

$$EF("H2") = \sum_e EC("H2", e) * EF(e) / H2$$

$$EF("ELE") = \left[\sum_e \{EC("ELE", e) + EC("CCS", e)\} * EF(e) - CCS \right] / ELE$$

EC: Energy consumption
EF: CO_2 emission factor
Heat: Heat production, *H2*: Hydrogen production, *ELE*: Electricity generation
CCS: Quantity of CO_2 capture and storage
e: Energy (COL, OIL, GAS, BMS, NUC, HYD, S/W)

4. CO_2 Gnr.
[Line 26]: Base year
[Line 47]: Scenario 1, Target year
[Line 68]: Scenario 2, Target year
CO_2 generations are shown automatically. The values are calculated by the following formulation.

*CO_2 generation = (Total energy consumption – Feedstocks) * CO_2 emission factor*

5. CO_2 CCS
[Line 27]: Base year
[Line 48]: Scenario 1, Target year
[Line 69]: Scenario 2, Target year
Enter quantity of CO_2 capture and storage.

6.CO_2 Ems.

[Line 28]: Base year

[Line 49]: Scenario 1, Target year

[Line 70]: Scenario 2, Target year

CO_2 emissions are shown automatically. The values are calculated by the following formulation.

$$CO_2\ emission = CO_2\ generation - CO_2\ CCS$$

Energy Balances / CO2 Emission

1990

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total	'90=100
CO2 Ems. (MtC)											284	100

2000

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total	'90=100
Energy Balances (Mtoe)												
Power Gnr.	37	23	51	92	84	7	3			-72	224	
CCS											0	
Heat											0	
Coal/Oil/Gas		11									11	
Hydrogen											0	
Industrial	46	99	10	7			0	0	0	28	190	
Residential	0	21	9	0			1	0	0	23	54	
Commercial	0	15	9	0			1	0	0	22	46	
Trans. Prv.	0	54	0	0			0	0	0	2	56	
Trans. Frg.	0	34	0	0			0	0	0	0	34	
Enduse	46	223	28	7			1	0	0	75	380	
Total	83	257	79	100	84	7	4	0	0	3	616	
Feedstock in total		31										
Emission Factor (MtC/Mtoe)	1.05	0.80	0.55	0.00	0.00	0.00	0.00	-	-	-		
CO2 Gnr. (MtC)	87	181	43	0	0	0	0	-	-	-	311	110
CO2 CCS (MtC)								-	-	-		
CO2 Ems. (MtC)	87	180.8	43	0	0	0	0	-	-	-	311	110

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total
CO2 Emission (MtC)											
Coal/Oil/Gas	0	9	0	0	0	0	0	0	0	0	9
Industrial	48	54	5	0	0	0	0	0	0	33	141
Residential	0	16	5	0	0	0	0	0	0	27	49
Commercial	0	12	5	0	0	0	0	0	0	26	43
Trans. Prv.	0	43	0	0	0	0	0	0	0	2	45
Trans. Frg.	0	27	0	0	0	0	0	0	0	0	28
Enduse	48	153	15	0	0	0	0	0	0	89	306
Total	48	162	15	0	0	0	0	0	0	89	315
Emission Factor	1.05	0.80	0.55	0.00	0.00	0.00	0.00	0.00	0.00	1.19	-

2050 A (CM)

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total	'90=100
Energy Balances												
Power Gnr.	18	9	37	69	84	8	3			-62	166	
CCS			2								2	
Heat											0	
Coal/Oil/Gas		3									3	
Hydrogen			18				13		-19		12	
Industrial	15	48	34	3			0	0	1	26	127	
Residential	0	1	1	0			8	0	4	14	28	
Commercial	0	1	1	0			3	0	3	19	26	
Trans. Prv.	0	4	0	3			0	0	5	2	14	
Trans. Frg.	0	2	0	1			0	0	6	1	10	
Enduse	15	56	36	7			11	0	19	62	205	
Total	33	67	93	76	84	8	27	0	0	0	388	
Feedstock in total		15										
Emission Factor (MtC/Mtoe)	1.05	0.80	0.55	0.00	0.00	0.00	0.00	-	-	-		
CO2 Gnr. (MtC)	34	42	51	0	0	0	0	-	-	-	127	45
CO2 CCS (MtC)			-30					-	-	-		
CO2 Ems. (MtC)	34	41.6	21	0	0	0	0	-	-	-	97	34

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total
Coal/Oil/Gas	0	2	0	0	0	0	0	0	0	0	2
Industrial	15	26	19	0	0	0	0	0	0	7	68
Residential	0	1	0	0	0	0	0	0	2	4	7
Commercial	0	0	0	0	0	0	0	0	1	5	8
Trans. Prv.	0	3	0	0	0	0	0	0	3	1	6
Trans. Frg.	0	1	0	0	0	0	0	0	3	0	5
Enduse	15	32	20	0	0	0	0	0	10	17	95
Total	15	35	20	0	0	0	0	0	10	17	97
Emission Factor	1.05	0.80	0.55	0.00	0.00	0.00	0.00	0.00	0.52	0.28	-

2050 B (CM)

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total	'90=100
Energy Balances												
Power Gnr.	5	6	33	31	37	8	8			-44	83	
CCS											0	
Heat											0	
Coal/Oil/Gas		2									2	
Hydrogen											0	
Industrial	14	40	26	16			0	0	0	21	117	
Residential	0	2	2	7			18	0	0	8	37	
Commercial	0	1	2	6			7	0	0	15	31	
Trans. Prv.	0	2	0	14			0	0	0	1	16	
Trans. Frg.	0	1	0	17			0	0	0	0	18	
Enduse	14	46	30	60			25	0	0	44	220	
Total	19	54	63	91	37	8	33	0	0	0	305	
Feedstock in total		15										
Emission Factor (MtC/Mtoe)	1.05	0.80	0.55	0.00	0.00	0.00	0.00	-	-	-		
CO2 Gnr. (MtC)	20	31	35	0	0	0	0	-	-	-	85	30
CO2 CCS (MtC)								-	-	-		
CO2 Ems. (MtC)	20	30.5	35	0	0	0	0	-	-	-	85	30

	COL	OIL	GAS	BMS	NUC	HYD	S/W	Heat	H2	ELE	Total
Coal/Oil/Gas	0	2	0	0	0	0	0	0	0	0	2
Industrial	15	20	14	0	0	0	0	0	0	13	62
Residential	0	1	1	0	0	0	0	0	0	5	7
Commercial	0	1	1	0	0	0	0	0	0	9	12
Trans. Prv.	0	1	0	0	0	0	0	0	0	0	2
Trans. Frg.	0	1	0	0	0	0	0	0	0	0	1
Enduse	15	24	16	0	0	0	0	0	0	28	83
Total	15	26	16	0	0	0	0	0	0	28	85
Emission Factor	1.05	0.80	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.63	-

Fig. 2.8 EB worksheet.

2.5 Factors

The “Factors” worksheet shows factors analysis of CO_2 emission. CO_2 emission is divided into four factors as follows.

$$C = D \times \frac{E}{D} \times \frac{C'}{E} \times \frac{C}{C'}$$

C: CO_2 emission, D: Driving force, E: Energy consumption
C’: CO_2 emission without countermeasure in energy transformation sector

Change of CO_2 emission is formulated as follows.

$$C + \Delta C = (D + \Delta D) \times (\frac{E}{D} + \Delta \frac{E}{D}) \times (\frac{C'}{E} + \Delta \frac{C'}{E}) \times (\frac{C}{C'} + \Delta \frac{C}{C'})$$

E/D: Energy intensity
C’/E: CO_2 intensity without countermeasure in energy transformation sector
C/C’: Change of CO_2 intensity by countermeasure in energy transformation sector

$$\frac{\Delta C}{C} = [\text{Contribution of } D\text{'s change}] + [\text{Contribution of } (E/D)\text{'s change}] + [\text{Contribution of } (C'/E)\text{'s change}] + [\text{Contribution of } (C/C')\text{'s change}]$$

$$\begin{aligned}[\text{Contribution of } D\text{'s change}] = {} & \frac{\Delta D}{D} + \frac{1}{2} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} + \frac{\Delta D}{D} \times \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta D}{D} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{3} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C/C')}{(C/C')} + \frac{\Delta D}{D} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{4} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right)\end{aligned}$$

$$\begin{aligned}[\text{Contribution of } (E/D)\text{'s change}] = {} & \frac{\Delta(E/D)}{(E/D)} + \frac{1}{2} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} + \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{3} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C/C')}{(C/C')} + \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{4} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right)\end{aligned}$$

$$\begin{aligned}[\text{Contribution of } (C'/E)\text{'s change}] = {} & \frac{\Delta(C'/E)}{(C'/E)} + \frac{1}{2} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{3} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} + \frac{\Delta D}{D} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} + \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{4} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right)\end{aligned}$$

$$\begin{aligned}[\text{Contribution of } (C/C')\text{'s change}] = {} & \frac{\Delta(C/C')}{(C/C')} + \frac{1}{2} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(C/C')}{(C/C')} + \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C/C')}{(C/C')} + \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{3} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C/C')}{(C/C')} + \frac{\Delta D}{D} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} + \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right) \\ & + \frac{1}{4} \times \left(\frac{\Delta D}{D} \times \frac{\Delta(E/D)}{(E/D)} \times \frac{\Delta(C'/E)}{(C'/E)} \times \frac{\Delta(C/C')}{(C/C')} \right)\end{aligned}$$

The explanation of the table in “Factors” is shown as follows.

[Line 6] Reduction rate of CO_2 emission by change of driving force
[Line 7] Reduction rate of CO_2 emission by change of energy intensity
[Line 8] Reduction rate of CO_2 emission by change of CO_2 intensity without

countermeasures in energy transformation sector.
[Line 9] Change of CO_2 intensity by countermeasure in energy transformation sector
[Line 10] Change of CO_2 emission in each sector compared to a base year.
[Line 11] CO_2 emission share in a base year.

		2050 A						2050 B					
		IND	RES	COM	TR-P	TR-F	Total	IND	RES	COM	TR-P	TR-F	Total
Change rate	D	-10%	-4%	7%	-12%	0%	-6%	-19%	-11%	-2%	-10%	-6%	-13%
2050/2000	E/D	-15%	-26%	-36%	-48%	-57%	-28%	-11%	-7%	-20%	-31%	-19%	-15%
	C/E	-5%	-10%	3%	-14%	-14%	-7%	-14%	-46%	-22%	-48%	-70%	-30%
	C'/C	-22%	-45%	-57%	-11%	-10%	-28%	-12%	-22%	-29%	-7%	-2%	-14%
	Total	-52%	-85%	-82%	-86%	-82%	-69%	-56%	-85%	-73%	-96%	-97%	-73%
CO2 share	2000	46%	16%	14%	15%	9%	100%	46%	16%	14%	15%	9%	100%

Fig. 2.9 Factors analysis table in factors worksheet.

2.6 EneEms

Graphs of energy consumption and CO_2 emission are shown in the “EneEms” worksheet.

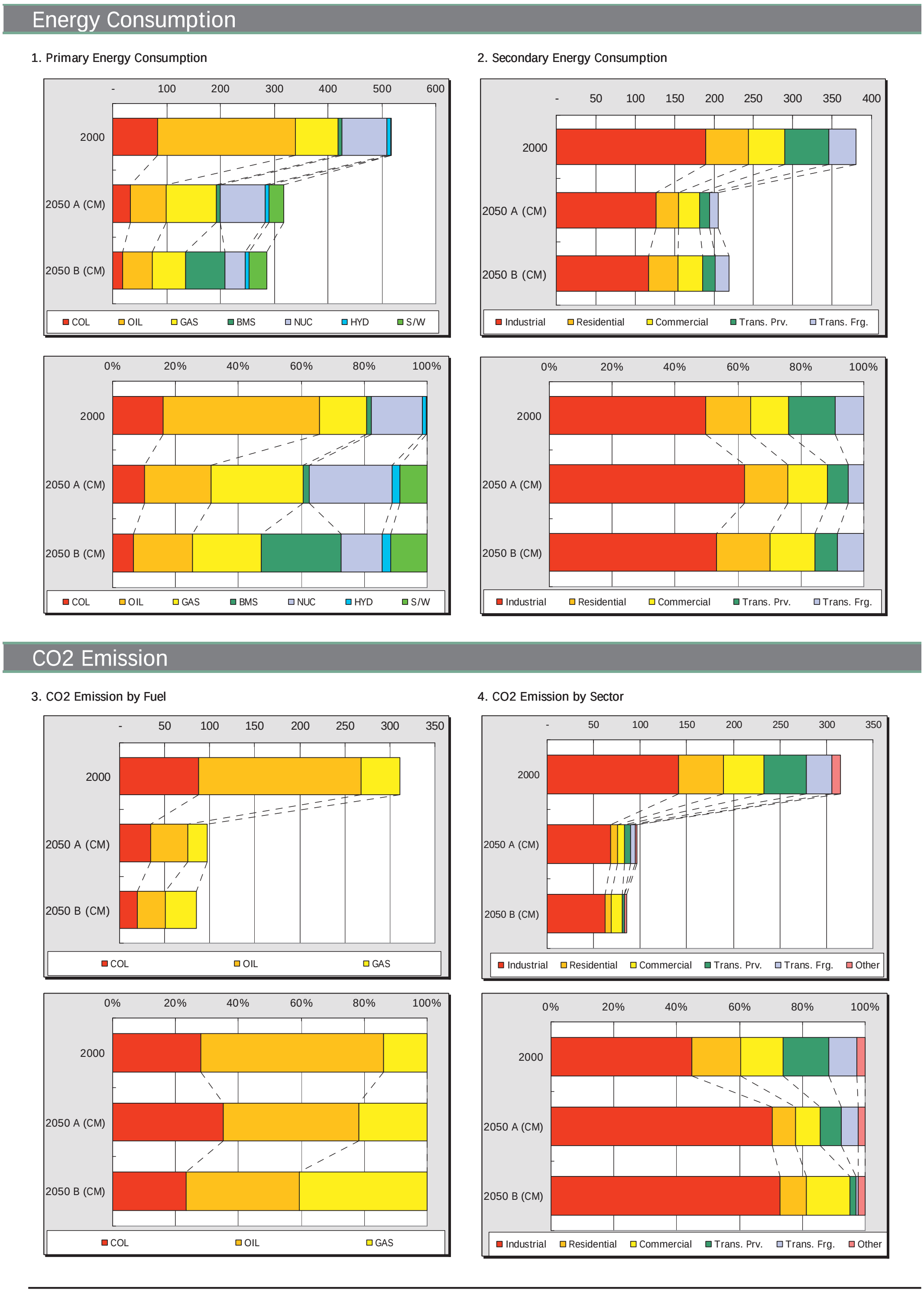


Fig. 2.10 Factors analysis figures in factor worksheet.

PART Ⅲ

AIM/Enduse Model

Manual

1. What is AIM/Enduse Model?

1.1 Characteristics of AIM/Enduse Model

AIM/Enduse is a bottom-up model of technology selection within a country's energy-economy-environment system. Technologies are selected in a linear optimization framework in which system costs are minimized by several constraints such as service demands and the availability of energy and materials. System costs include fixed costs, the operating costs of technologies, energy costs, taxes and subsidies, etc. The AIM/Enduse model can simultaneously calculate the costs for multiple years. It can also analyze various scenarios, including policy countermeasures.

1.2 Structure of AIM/Enduse Model

1.2.1 Input

1) Element of indices

Table 1.2.1 Element of indices

Indices	Code in AIM/Enduse
Emission Type	M
Sector	I
Service Type	J
Device	L
Removal process	P
Energy type	K
Year	Y

2) Parameters

Table 1.2.2 Exogenous parameters in AIM/Enduse

Outputs
Emission Factor (K,M,Y)
Energy Price (K,Y)
Service Demand (I,J,Y)
Technology Specification (L,J,K,M,P,Y)
Combination of Internal Energy and Service (J,K)
Stock in Base Year (I,L,P)
Maximum Share (I,J,L,Y)
Social Service Efficiency (I,K,L)
Operating rate (I,L,Y)
Energy Efficiency Improvement (L,K,L)
Subsidy Rate (L,P,Y)
Energy/Emission Tax (I,K,Y)/(I,M,Y)
Energy/Emission Constraint

1.2.2 *Output*

Table 1.2.3 AIM/Enduse Output

Outputs
Energy Consumption (I,K,L,P,Y)
Emission Quantity (I,L,M,P,Y)
Service Supply (I,J,L,P,Y)
Operating Quantity (I,L,P,Y)
Recruitment Cost (I,L,P,Y)
Operating Cost (I,L,P,PI,Y)
Exchanging Cost (I,L,P,P1,Y)
Tax Payment (I,L,P)

1.2.3 *Calculation flow*

Fig.1.2.1 shows the structure of the AIM/Enduse Model. “Energy technology” refers to a device that provides a useful service by consuming energy. “Energy service” refers to a measurable need that must be satisfied. For example, in the residential sector, the air conditioner is an energy technology and space cooling is an energy service. In the transportation sector, a vehicle is an energy technology and the transportation of people is an energy service. The unit of energy service varies with the type of service.

The energy-service demands used in this model are based on scenarios or results obtained from other models. The combination of technologies is then endogenously calculated according to the logic shown below in order to satisfy service demands. Next, the energy consumption is calculated from the specific energy consumption of each technology and the combination of technologies. Finally, the CO_2 emissions are calculated from the energy consumption and emission factors for each energy type.

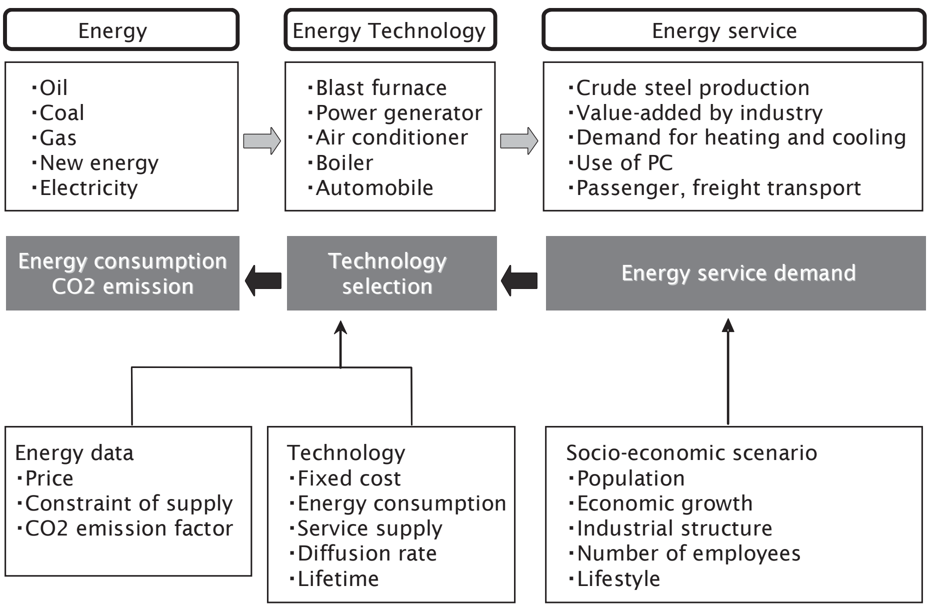


Fig. 1.2.1 Structure of AIM/Enduse Model.

The AIM/Enduse Model creates combinations of energy technologies in order to minimize the total annual cost of supplying energy services under several constraints, such as the availability of energy and the maximum share of technology diffusion. The payback time method expresses the total annual cost. In Fig.1.2.2, the payback period is three years.

Three types of cohort changes are taken into account simultaneously in the AIM/Enduse Model: 1) recruitment of a new technology at the end of the service life of an older technology or when energy service demand increases; 2) improvement of an existing technology; and 3) replacement of an existing technology, even though the existing technology remains in service. In the first case, the least costly technology in terms of the initial cost and the 3-year running cost, including energy and maintenance costs, is selected. In the second case, improvements are adopted by comparing the total cost (the necessary improvement cost and the running cost for 3 years after the improvement) and the 3-year running cost before improvement. In the third case, the 3-year running cost of the working technology is compared with the total cost (the initial cost and the 3-year running cost of the new related technology). In the third case, a new energy-saving technology should be selected only when the initial cost of the technology is less than the difference in the running costs for the old and new technologies for the duration of the payback period. Thus, it is more difficult to select an energy-saving technology in the third case than in the first case.

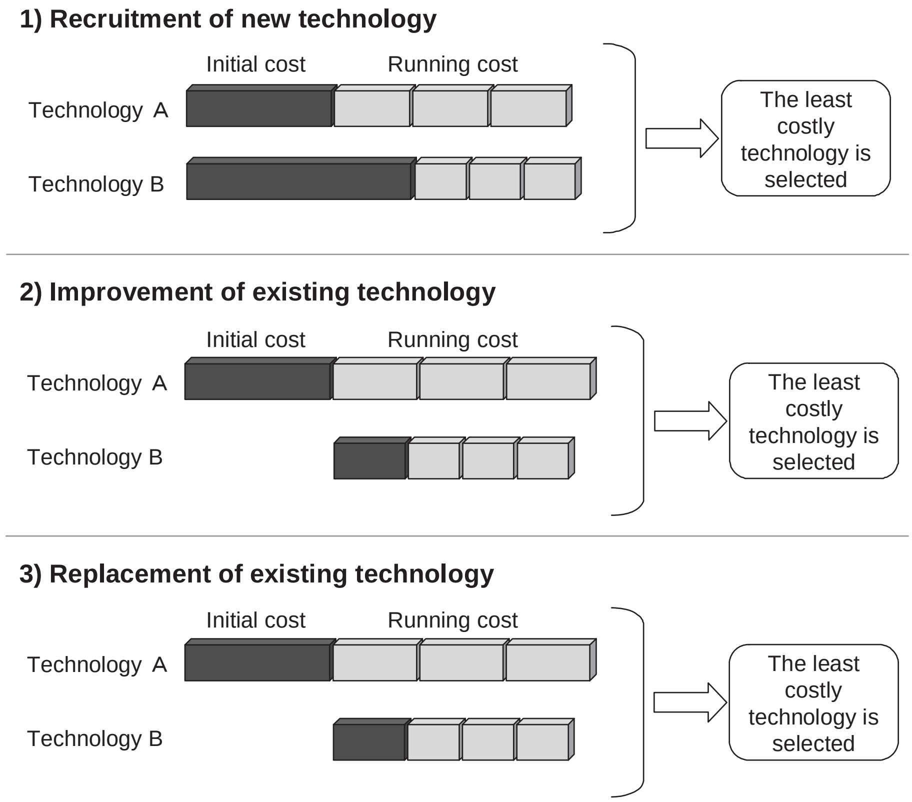


Fig. 1.2.2 Logic of technology selection.

1.3 AIM/Enduse Software

1.3.1 System requirement

GAMS must be installed on user's PC so as to execute the program of AIM/Enduse Model. See Chapter 2.1.2 "Instllation of GAMS".

1.3.2 AIM/Enduse Software

AIM/Enduse software comprises an integration of Optimization system (GAMS), Database system (MS-Access). The mathematical formulation (see Appendix C) is written and solved in GAMS. AIM/Enduse database system, developed using MS-Access, is the interface for GAMS program. It can supply input data for GAMS program file AIM-CMB.gms and display results of simulation. It also provides a user-friendly interface to the user for input of data, and design and analysis of scenarios or countermeasures (see Chapter 2).

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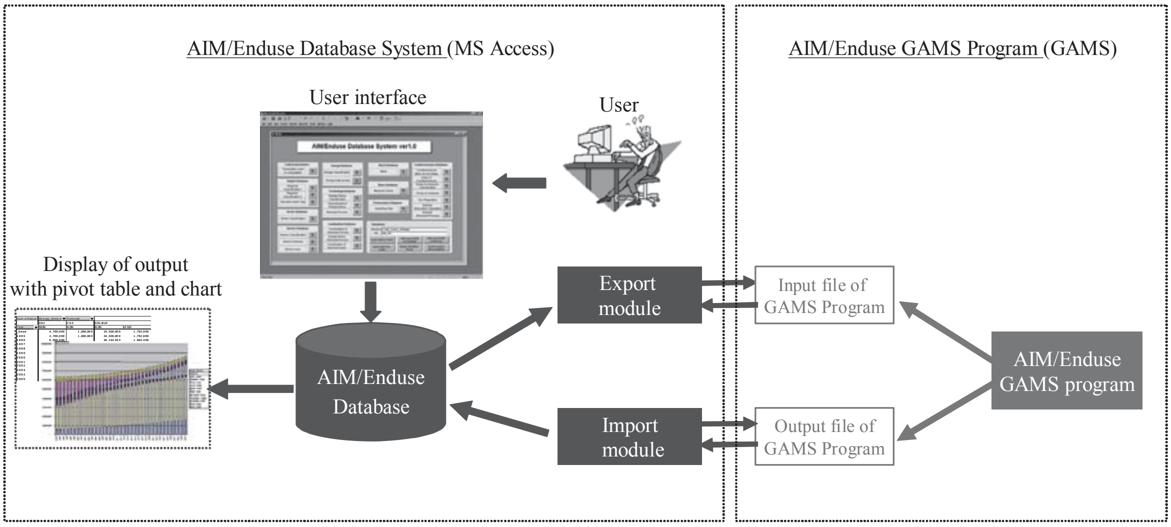

Fig. 1.3.1 AIM/Enduse software.

2. How to use AIM/Enduse Model

2.1 Installation of AIM/Enduse

2.1.1 AIM/Enduse

AIM/Enduse contains the following files.

¥AIM_Enduse¥src	¥AIM_CMB.gms	AIM/Enduse GAMS program (main)
	¥_errorout.gms	AIM/Enduse GAMS program (sub)
	¥_interp.gms	AIM/Enduse GAMS program (sub)
	¥_printout.gms	AIM/Enduse GAMS program (sub)
¥data	¥AIM_Enduse.mdb	AIM/Enduse database system
	¥Japan.mdb	AIM/Enduse database system (for Japanese version)
	¥Ex1(answer).mdb	AIM/Enduse database system
	¥Ex2(answer).mdb	AIM/Enduse database system
	¥ AIM_Enduse.inp	Control file
¥GAMS_inclib	¥(42 files)	

2.1.2 Installation of GAMS

1) Double click setup.exe in “GAMS distribution”and install GAMS distribution

2) Copy the files in ¥GAMS_inclib to gams22.2¥inclib on your PC. There are some library files which are needed by AIM/Enduse.

2.1.3 Installation of AIM/Enduse Database

1) Make “AIM/Enduse” under your working directory, and copy “data”. After copying, cancel read-only attributes of the files.

2) AIM/Enduse Database needs Microsoft DAO 3.6 Object Library. To export simulation results for displaying emission distribution, Microsoft ADO Ext. 2.5 for DDL and Security is necessary. If the libraries are not referred, the system does not work well. After installation, check references if it shows same order as follows.

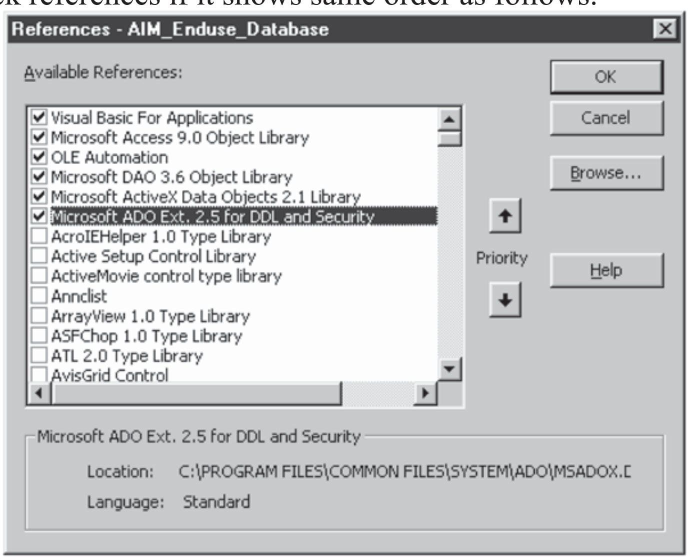

Fig. 2.1.1 References of AIM/Enduse Database.

How to display the above window.

- Open AIM_Enduse.mdb.
- Select “Modules” in “Object”.
- Click “GAMS_INPUT”. VBA editing window appears.
- Select “Tools” -> “References”.

2.1.4 Installation of AIM/Enduse GAMS program Database

1) Copy “src” under “AIM/Enduse”.

2) GAMSIDE is a graphical interface to create, debug, edit and run GAMS files. At first time you must create GAMS project file in ‘src’ directory as follows.
cf.) GAMSIDE manual : http://www.gams.com/mccarl/useide.pdf

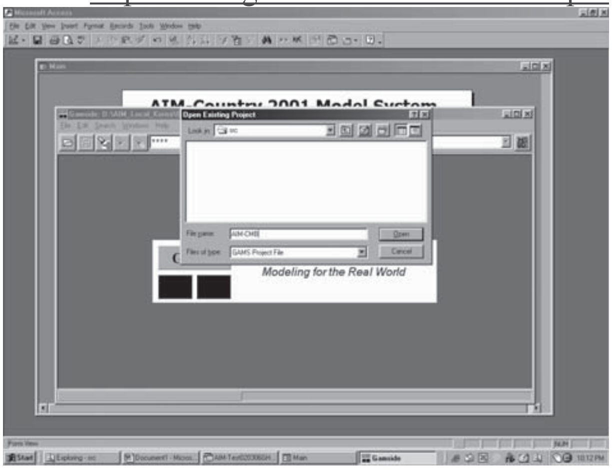

Fig. 2.1.2 GAMS project file.

3) AIM/Enduse GAMS program needs CPLEX as linear programming solver. Select CPLEX as shown in Fig. 2.1.3.
How to display the above window.

- “File” → “Options” → “Solvers”

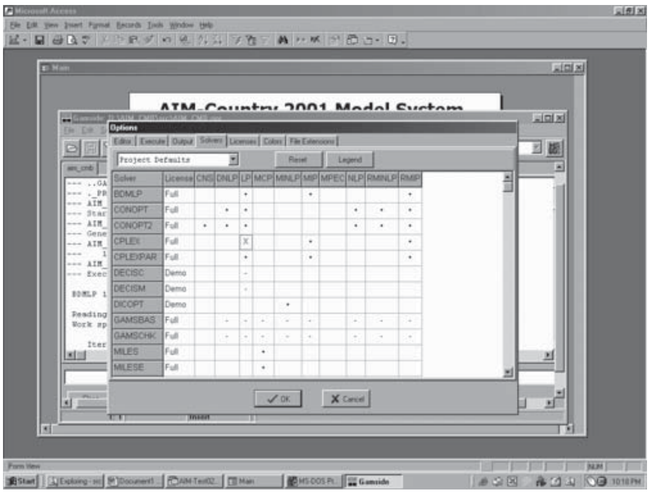

Fig. 2.1.3 Selection of CPLEX.

2.2 Description of input data

“Main” form as shown in Fig. 2.2.1 appears on clicking at file AIM_Enduse.mdb on Windows explorer. Input data is entered by clicking on the buttons in the main form.

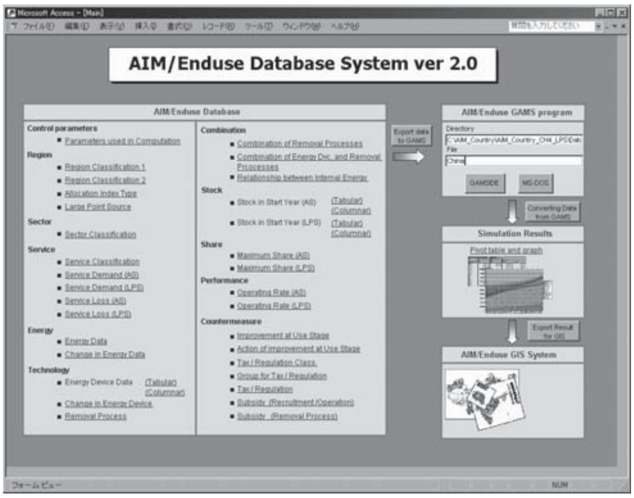

Fig. 2.2.1 After clicking AIM_Enduse.mdb.

2.2.1 Control parameters

1) Parameters used in computation

The list of parameters used in computation is shown in the following table.

Table 2.2.1 List of items in "Parameters used in computation"

Items	Format	Contents
Start year of calculation*	Integer	Year from which AIM/Enduse calculates energy consumption, greenhouse gases and air pollutants emissions. It corresponds to the base year.
End year of calculation*	Integer	Year to which AIM/Enduse calculates energy consumption, greenhouse gases and air pollutants emissions.
Discount rate*	Percent	Rate is used for economic criteria of technology selection based life cycle cost.
Unit of price*	Chr. (Max 50)	Change of unit could not cause the exchange of values.
Unit of energy*	Chr. (Max 50)	
Greenhouse Gases/Air Pollutant		
No	Number	Code and unit of greenhouses gases and unit.
Code*	Chr. (Max 10)	
Unit *	Chr. (Max 50)	

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.2 Region database

1) Region classification 1

This table specifies the aggregate region classification. Service demand, technologies' share and countermeasure etc. should be listed by this classification.

Table 2.2.2 List of items in "Region classification 1"

Items	Format	Contents
No.	Integer	Number of the coarse region classification. It is an independent number and is not used in the calculation.
Region 1 code*	Chr. (Max 10)	Code of the coarse region classification. Every code must be unique in the list. - "ALL" could not be permitted to use as the code. - "_" could not be permitted to use as a part of the code.
Region 1 name	Chr. (Max 50)	Name of the coarse region classification.

Item with * : Code or value of the item is indispensable for database system and calculation.

2) Region classification 2

This table specifies the fine regional classification. AIM/Enduse converts emission data to the one by this classification for display on GIS. The classification is corresponds to cities and counties.

Table 2.2.3 List of items in "Region classification 2"

Items	Format	Contents
No.	Integer	Number of the coarse region classification. It is an independent number and is not used in the calculation.
Region 1 code*	Chr. (Max 10)	Code of the coarse region classification. Every code must be unique in the list.
Region 1 name	Chr. (Max 50)	Name of the coarse region classification.
GIS Code		The code of region ID on ISRISI system. If you do not display emission on GIS, you do not need to input data.
Region 1*	-	Select the regional classification 1 that the regional classification 2 belongs to in the list.
Area*	Single	An area by classification. The unit is km2.
Allocation Index (First index =*)	Single	Select the allocation index on the head. Input the quantity of the allocation index by classification.

Item with * : Code or value of the item is indispensable for database system and calculation.

3) Allocation Index Type

In case of area source, firstly, its emission is calculated by each regional classification 1 (coarse classification). Then it allocates the emission to the regional classification 2 (detailed classification) in proportion to allocation index's quantity. The type given in "Allocation Index" should be listed in this table.

Table 2.2.4 List of items in " Allocation index type"

Items	Format	Contents
No.	Integer	The number of the allocation index type. It is an independent number and is not used in the calculation.
Index Code*	Chr. (Max 10)	The code of the allocation index type. Every code must be unique in the list.
Index Name*	Chr. (Max 50)	The name of the allocation index type.

Item with * : Code or value of the item is indispensable for database system and calculation.

4) LPS

This table specifies the attribution of large point sources.

Table 2.2.5 List of items in " LPS"

Items	Format	Contents
No.	Integer	The number of the large point source. It is an independent number and is not used in the calculation.
LPS Code*	Chr. (Max 20)	The code of the large point source. Every code must be unique in the list.
LPS Name*	Chr. (Max 100)	The name of the large point source.
Region 2*	-	Select the fine regional classification that the large point source LPS belongs to in the list.
Operation Rate*	Percent (0%-100%)	The operation rate of the technologies at the large point source. The rate of each technology and by year could be listed in operation rate table.
Longitude	Single (-180~+180)	Specify to 100ths of degrees, not minutes/seconds; + for east, - for west. (It is not used in this version)
Latitude	Single (-90~+90)	Specify to 100ths of degrees, not minutes/seconds; + for north, - for south. . (It is not used in this version)
Stack height	Single ($0\sim10^4$)	The stack height of the large point source. The unit is meter. . (It is not used in this version)

2.2.3 Sector database

1) Sector classification

This table specifies the sector classification. AIM/Enduse shows emission by each sector based on this classification. Also, countermeasure scenarios can be set for each sector.

Table 2.2.6 List of items in "Sector classification"

Items	Format	Contents
No.	Integer	Number of the sector classification. It is an independent number and is not used in the calculation.
Sector code*	Chr. (Max 10)	Code of the sector classification. Every code must be unique in the list. - "ALL" could not be permitted to use as the code. - "_" could not be permitted to use as a part of the code.
Sector name	Chr. (Max 50)	Name of the sector classification.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.4 Service database

1) Service classification

This table specifies the service classification.

Table 2.2.7 List of items in "Service classification"

Items	Format	Contents
No.	Integer	Number of the energy classification. It is an independent number and is not used in the calculation.
Service code*	Chr. (Max 10)	Code of the service classification. Every code must be unique in the list.
Service name	Chr. (Max 50)	Name of the service classification.
Service unit	Chr. (Max 10)	Unit of the service classification.
Sector name*	-	Select the sector that the service belongs in the list.
Allocation index	-	In case of area source, firstly, its emission is calculated by each region classification 1. Then emission is allocated to the region classification 2 in proportion to allocation index. Select the number and the name of the allocation index by which the emission is divided to the classification 2.

Item with * : Code or value of the item is indispensable for database system and calculation.

2) Service demand (AS/LPS)

The data for service demand in reference year as well as its projections in future years are entered in this table.

Table 2.2.8 List of items in "Service demand"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Region 1* (in case of AS)	-	Select the coarse region classification in the list.
LPS* (in case of LPS)	-	Select the LPS in the list.
Service*	-	Select the service classification in the list. Every pair of 'Region 1' and 'Service' must be unique.
Service demand (year) * Service demand (value) *	Integer Single (>0)	Enter data sets given by pairs of year and quantity. The total sets are less than four. Temporary value may be entered as the demand of internal service so that the one is decided endogenously in the model.

Item with * : Code or value of the item is indispensable for database system and calculation.

3) Service loss (AS/LPS)
Data for transmission and distribution loss between the producer and the receiver of energy service is entered in this table. If no data in entered in this table for a service, its transmission and distribution loss is assumed as 0%.

Table 2.2.9 List of items in "Service loss"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Region 1* (in case of AS)	-	Select the region classification 1 in the list.
LPS* (in case of LPS)	-	Select the LPS in the list.
Service*	-	Select the service type in the list.
Service loss rate (year)*	Integer	Enter data sets given by pairs of year and quantity. The total sets are
Service loss rate (value)*	Single	less than four.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.5 Energy database

1) Energy data
Energy data is listed in this table.

Table 2.2.10 List of items in "Energy data"

Items	Format	Contents
No.	Integer	Number of the energy classification. It is an independent number and is not used in the calculation.
Energy code *	Chr. (Max 10)	Code of the energy classification. Every combination of energy code and region 1 be unique in the list.
Energy name	Chr. (Max 50)	Name of the energy classification.
Energy price *,+	Single	Energy price by energy type with the unit shown in the heading row.
Emission factor	Single	Select the gas type in the list in the heading row. Emission factor by energy type with the unit shown in the heading row.

Item with * : Code or value of the item is indispensable for database system and calculation.

Item with + : If the factor is not constant year by year, check the box and enter the value in "Energy Data by year" table.

2) Change in energy data
This table shows energy price, CO_2 emission factor, SO_2 emission factor and NOx emission factor by year. If this data is constant by year, this table is not needed. Data in this table is considered only when corresponding row in table "Energy Classification" is checked.

Table 2.2.11 List of items in "Change in energy data"

Items	Format	Contents
No.	Integer	Number of the energy classification. It is an independent number and is not used in the calculation.
Energy*	-	Select the energy type of which energy price or emission factor changes year by year in the list.
Price or gas*	-	Select energy price or type of emission gas in the list.
Energy factor (year) *	Integer	A set of data is given by a pair of year (year) and price/emission factor
Energy factor (year) *	Single	(value). The total sets are less than four. The value is entered with the units shown in the footer of the form.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.6 Technology database

"Technology" includes two types of devices, one is energy devices and another is removal processes. Energy device refers to the technology which consumes energy and supply service in order to satisfy service demand. Removal process refers to the technology which removes air pollutants emitted by a energy device.

1) Energy device data (Tabular/Column)
Energy device data is listed in this table.

Table 2.2.12 List of items in "Energy device data"

Items	Format	Contents
No.	Integer	Number of the energy device. It is an independent number and is not used in the calculation.
Energy device code *	Chr. (Max 10)	Code of the energy device. Every code must be unique in the list.
Energy device name	Chr. (Max 10)	Input the name of the technology. Maximum number of characters is 40.
Life time *	Single (>0)	Life time of the energy device.
Device unit	Chr. (Max 10)	Unit which service supply and energy consumption of each technology based on.
Specific service output		
(Name) *	-	Select the service the technology supplies in the list.
(Quantity) *,+	Single (>0)	Service supply of an energy device per year and per device unit is listed.
Fixed cost *,+	Single (≧0)	Fixed cost of the energy device per device unit. The value is entered with the units shown in the footer of the form.
Operation cost +	Single (≧0)	Operation cost of the energy device. The value is entered with the units shown in the footer of the form.
Specific energy consumption		
(Name) *	-	Select the type of energy or material that the energy device consumes in the list.
(Quantity) *,+	Single	Energy or material consumption of the energy device per unit is listed. Energy consumption is entered with the unit shown in the footer of the form.
(Non-energy use)	Single	Ratio of energy or material except combustion use. If the rate is equal to 100%, each gas does not be emitted
Gas emission ex. fuel content +		
(Name)	-	Select the type of gas in the list
(Quantity)	Single	Gas emission other than fuel content.

Item with * : Code or value of the item is indispensable for database system and calculation.
Item with + : If the value is not constant, click the box and enter time-series value in "Improvement of Energy Device" table.

2) Change in energy device data
Change in energy device data is listed in this table. Data in this table is considered only when corresponding row in "Energy Device Classification" table is checked.

Table 2.2.13 List of items in "Change in energy device"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Energy device*	-	Select the energy device in the list.
Improved item*	-	Select the item whose quantity is improved. Every pair of 'Energy Device' and 'Improved Item' must be unique.
Improvement (year)*	Integer	Input data sets given by pairs of year and quantity. The total sets are less than
Improvement (value)*	Single	four. The value is entered with the units shown in the footer of the form.

Item with * : Code or value of the item is indispensable for database system and calculation.

3) Removal process
This table specifies the classification of air pollution removal processes.

Table 2.2.14 List of items in "Removal process"

Items	Format	Contents
No.	Integer	Number of the removal process classification. It is an independent number and is not used in calculation.
Removal process code*	Chr. (Max 10)	Code of the removal process classification. Every code must be unique in the list.
Removal process name*	Chr. (Max 40)	Name of the removal process.
Stage of process*	-	Select at which stage the control is done. Pre-combustion: coal screening, coal washing etc. In Situ Combustion: lime stone injection into furnace etc. Post-combustion: flue gas desulfurization, selective catalytic reduction etc.
Fixed cost	Single	Fixed cost of the removal process per energy consumption of energy device with the unit shown in the heading row.
Operation cost	Single	Operation cost of the removal process per year and per energy consumption of energy device with the unit shown in the heading row.
Energy consumption	Single	Energy consumption of the removal process per energy consumption of energy device with the unit shown in the heading row.
Removed gas		
(Gas)	-	Select the type of gas removed by the process.
(Removal rate)	Percentage	Removal rate to mitigate for air pollution emission by control.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.7 Combination database

In combination database, users must set two types of combination. One is the combination concerning removal process. Firstly, users set the combination of removal processes by selecting each process at pre-combustion, in-site and post-combustion in "Combination of Removal Process" table. Next, users set the combination of energy devices and removal processes in "Combination of Energy Devices and Removal Processes".
Another is the combination concerning energy devices. In case that a device consumes output from others as input, users set the linkage between input and output in "Combination of Input and Output of Energy Devices".

1) Combination of removal processes
Combination of removal processes is assembled in this table. In case that removal processes are not introduced, this table can be ignored.

Table 2.2.15 List of items in "Combination of removal processes"

Items	Format	Contents
No.	Integer	Number of the combination of removal process. It is an independent number and is not used in the calculation.
Combination of removal processes		
(Code) *	Chr. (Max 10)	Code of the combination of removal process. Every code must be unique. "NON" cannot be used as a code.
(Name)	Chr. (Max 50)	Name of the combination of the removal process.
Removal process *	-	Select the removal process at each stage.
Removal rate	-	Removal rate of the combination is calculated automatically after clicking "UPDATE".
Fixed cost, Operation cost, Energy consumption	-	Fixed cost, operation cost and energy consumption of the combination is calculated automatically after clicking "UPDATE".

Item with * : Code or value of the item is indispensable for database system and calculation.

2) Combination of energy device and removal processes
Combination of energy device and removal processes is assembled in this table.

Table 2.2.16 List of items in "Combination of energy device and removal processes"

Items	Format	Contents
Energy device *	-	Select the energy device from the upper box.
No.	Integer	Number of the combination of energy device and removal process. It is an independent number and is not used in the calculation.
Code	-	Code of the combination of energy device and removal process is determined automatically after selecting removal process.
Combination of energy device and removal processes	Chr. (Max 50)	Name of the combination of energy device and removal process.
Combination of removal processes *	-	Select the combination of the removal process.

Item with * : Code or value of the item is indispensable for database system and calculation.

3) Relationship between internal energy/service
Relationship between internal energy/service is assembled in this table.

Table 2.2.17 List of items in "Relationship between internal energy/service"

Items	Format	Contents
No.	Integer	Number of the combination of input and output of energy devices. It is an independent number and is not used in the calculation.
Internal energy *	-	Internal energy is selected to combine with internal service.
Internal service*	-	Internal service is selected to combine with internal service.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.8 Stock database

1) Stock in start year (AS/LPS)(Tabular/Columnar)
This table specifies the stock of each combination of device and removal process in start year of calculation.

Table 2.2.18 List of items in "Stock in start year"

Items	Format	Contents
No.	Integer	Number of the dataset. It is an independent number and is not used in the calculation.
Region 1 *	-	Select the coarse region classification.
Energy device *	-	Select the energy device.
Combination of removal process *	-	Select the combination of removal process.
Stock	Single	Stock quantity in the start year of calculation.
Specific service output		
(Name)	-	Service name is shown automatically after selecting an energy device.
(Value)+	Single	Value is shown automatically after selecting an energy device.
Fixed cost / operation cost	Single	Value is shown automatically after selecting an energy device.
Specific energy consumption		
(Name)	-	Energy name is shown automatically after selecting an energy device.
(Value) +	Single	Value is shown automatically after selecting an energy device.
(Non energy)	Single	Value is shown automatically after selecting an energy device.
Removal Rate		
(Gas)	-	Gas type is shown automatically after selecting an energy device.
(Removal Rate) +	Single	Value is shown automatically after selecting an energy device.
Gas emission ex. fuel content +		
(Name)	-	Select the type of gas in the list
(Quantity) +	Single	Value is shown automatically after selecting an energy device.

Item with * : Code or value of the item is indispensable for database system and calculation.
Item with + : The value can be changed from the defaults. If the option button is false, the change is invalid.

2.2.9 Share database

1) Maximum share of energy device (AS/LPS)
Maximum share of energy device in satisfying a service is entered in this table. This table is necessary only for the devices whose share is bound by upper limit.

Table 2.2.19 List of items in "Maximum share of energy device"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Region 1*	-	Select the coarse region classification.
LPS*	-	Select the coarse region classification.
Service *	-	Select the service classification in the list.
Energy device*	-	Select the energy device in the list.
Maximum share (year) *	Integer	Enter data sets given by pairs of year and quantity. The total sets are less
Maximum share (value) *	Single (%)	than four.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.10 Performance database

1) Operating rate (AS/LPS)
Operating rate of a device is entered in this table. If this value is not entered by the user, default value of operating rate is assumed as 100% in the model.

Table 2.2.20 List of items in "Operating rate"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Region 1*	-	Select the region classification 1 in the list.
Energy device*	-	Select the energy device in the list.
Operation rate (year) *	Integer	Enter data sets given by pairs of year and quantity. The total sets are less
Operation rate (value) *	Single	than four.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.2.11 Countermeasure database

AIM/Enduse can estimate energy consumption, greenhouse gases emission and air pollutants emission with countermeasures. Following countermeasures can be set in the model: (i) Countermeasure at use stage; (ii) Tax for energy consumption, greenhouse gases emission and air pollutants emission; (iii) Regulation for energy consumption and emissions; (iv) Subsidy for recruited technology and exchange etc.

1) Improvement at use stage
Change in life style and method of use and maintenance of devices can result in conservation of energy at use stage. This table shows improvement at use stage of energy device.

Table 2.2.21 List of items in "Improvement at use stage"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Code *	-	Code of the countermeasure at used stage.
Content of countermeasure	Chr. (Max 100)	Content of the countermeasure at used stage.
Energy device *	-	Select the energy device in the list.
Reduction rate *	Single	Rate of reduction of service supply or energy use.

Item with * : Code or value of the item is indispensable for database system and calculation.

2) Action of improvement at use stage
Action rate of improvement at use stage in the region is listed in the table.

Table 2.2.22 List of items in "Action of improvement at use stage"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Region 1 /LPS *	-	Select the coarse region classification or the LPS in the list.
Improvement at use stage *	-	Select the countermeasure menu in the list.
Action rate		
(year) *	Integer	Enter data sets given by pairs of year and quantity. The total sets are
(value) *	Percent	less than four.

Item with * : Code or value of the item is indispensable for database system and calculation.

3) Tax/regulation classification
User can set the countermeasure as tax or restriction (constraint) by emission type and/or energy.

Table 2.2.23 List of items in "Tax/regulation classification"

Items	Format	Contents
No.	Integer	Number of the data sets. It is an independent number and is not used in the calculation.
Group code*	Chr. (Max 10)	Code of the group.
Countermeasure type*	-	Select the countermeasure type in the following choices.
Group name*	Chr. (Max 50)	Name of group.

Item with * : Code or value of the item is indispensable for database system and calculation.

4) Group for tax/regulation
The tax and constraints defined in previous section can be applied to selected sectors in this table.

Table 2.2.24 List of items in "Group for tax/regulation"

Items	Format	Contents
No.	-	These data are shown automatically.
Region 1 *	-	
Sector *	-	
Countermeasure Group	-	Select group on measure.

Item with * : Code or value of the item is indispensable for database system and calculation.

5) Tax / regulation
Tax rate or regulation for each group is listed in this table. If the tax rate or regulation is not entered for a group, tax rate is assumed zero or regulation is assumed infinite.

Table 2.2.25 List of items in "Tax / regulation"

Items	Format	Contents
(check box)	-	If you do not check, the rate is ignored.
Group *	-	Select the group in the list quoted from "Group on Measure Classification" table.
Type	-	Countermeasure type is shown after selecting group.
Energy *	-	If the countermeasure is energy tax or energy constraint, select the energy classification.
Tax rate/regulation (year) *	Integer	Input data sets given by pairs of year and quantity. The total number of
Tax rate/regulation (value)*	Percent	sets is less than four. The unit is shown in the type field.

Item with * : Code or value of the item is indispensable for database system and calculation.

6) Subsidy (recruitment & operation)

The subsidy rate for recruitment (fixed cost) or operation (operational cost) can be entered in this table.

Table 2.2.26 List of items in "Subsidy (recruitment & operation)"

Items	Format	Contents
(check box)	-	If you do not check, the rate is ignored.
No.	Integer	The number of the data sets. It is an independent number and is not used in the calculation.
Energy device *	-	Select the energy device in the list.
Combination of removal processes *	-	Select the combination of removal processes.
For recruitment/operation	-	Select 'for recruited' for subsidy at recruited stage, and 'for operation' for subsidy at operation for technology.
Subsidy rate (year) *	Integer	Input data sets given by pairs of year and quantity. The total sets are less
Subsidy rate (value) *	Percent	than four.

Item with * : Code or value of the item is indispensable for database system and calculation.

7) Subsidy (removal process)

The subsidy rate at recruited or exchange stage for removal process is listed in this table.

Table 2.2.27 List of items in "Subsidy (removal process)"

Items	Format	Contents
No.	Integer (Max 32768)	The number of the data sets. It is an independent number and is not used in the calculation.
Removal process*	-	Select the energy device in the list.
Combination of removal process 1*	-	Select the combination of removal processes that may be exchanged to new one.
Combination of removal process 2*	-	Select the combination of removal processes that may be exchanged from old one.
Subsidy rate (year) *	Integer	Input data sets given by pairs of year and quantity. The total sets are less
Subsidy rate (value) *	Percent	than four.

Item with * : Code or value of the item is indispensable for database system and calculation.

2.3 Implementation

2.3.1 How to export input files for AIM/Enduse

1. "Data" directory and "Src" directory are set under the same directory as shown in Fig. 2.3.1. User should confirm the following program sources in "src" directory.
    - AIM_CMB.gms
    - _interp.gms
    - _printout.gms
    - _errorout.gms

2. Input directory and file name of GAMS input file in the "AIM/Enduse GAMS program" box on main form as shown in Fig. 2.3.2.

3. If user clicks on "Export data to GAMS", the interface exports input files for AIM-CMB.gms. After export of GAMS input files, the message appears as shown in Fig. 2.3.3. The new files, ****_1.gms, ****_2.gms, ****.set and ****.err, are made in "data" directory.

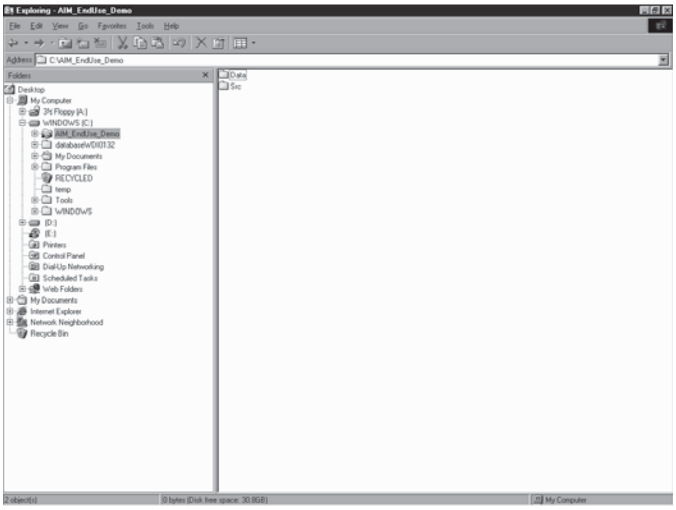

Fig. 2.3.1 How to export input files for AIM/Enduse GAMS version (1).

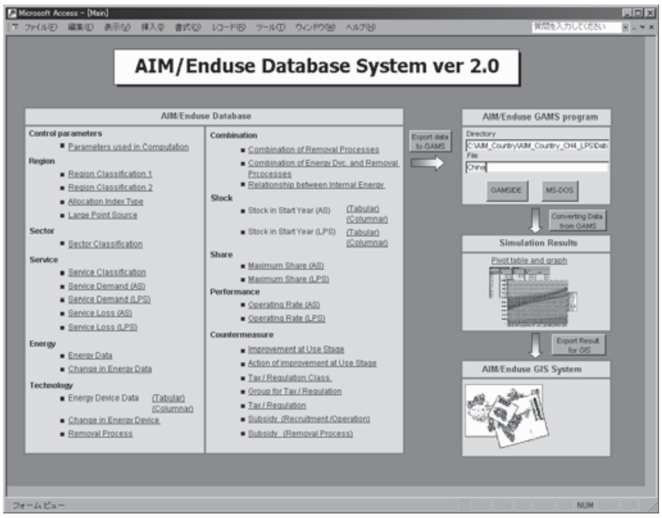

Fig. 2.3.2 How to export input files for AIM/Enduse GAMS version (2).

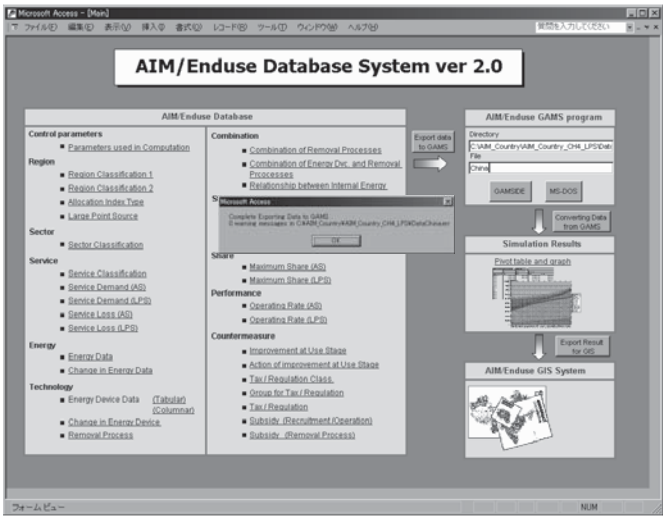

Fig. 2.3.3 How to export input files for AIM/Enduse GAMS version (3).

2.3.2 How to implement AIM/Enduse GAMS version

GAMSIDE is a graphical interface to create, debug, edit and run GAMS files. At first time user must create GAMS project file in 'src' directory as shown in Fig.2.3.4. After creating the file in 'src', user must open 'AIM_CMB.gms' file and run it. If the model runs normally, user can see the screen as shown in Fig. 2.3.7. As for how to use GAMSIDE, see the following file: GAMSIDE manual : http://www.gams.com/mccarl/useide.pdf

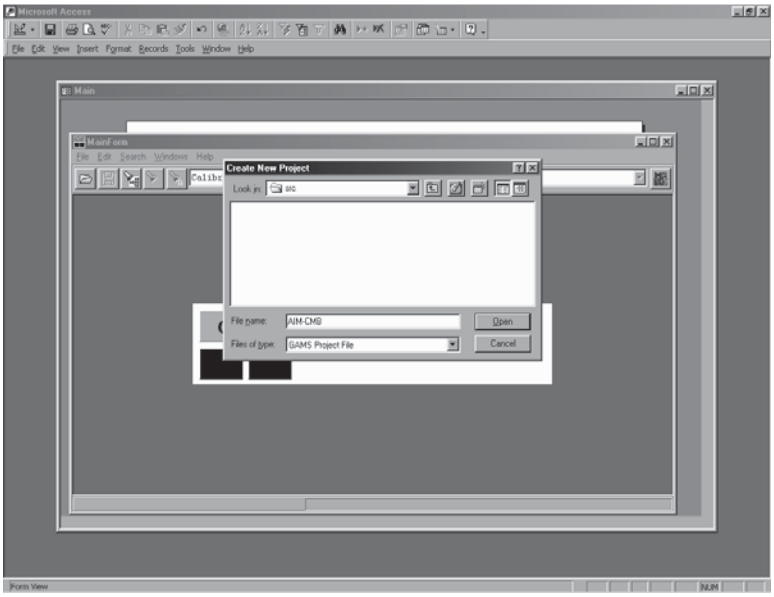

Fig. 2.3.4 How to implement AIM/Enduse GAMS version (1).

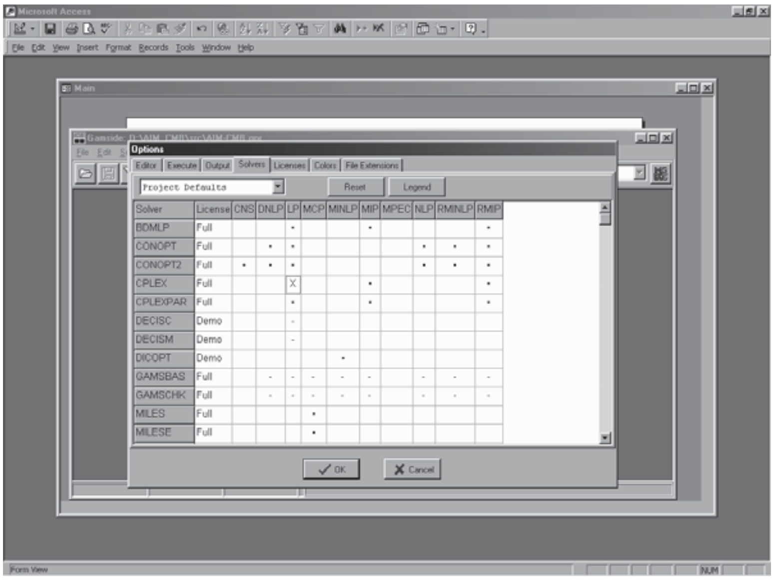

Fig. 2.3.5 How to implement AIM/Enduse GAMS version (2).

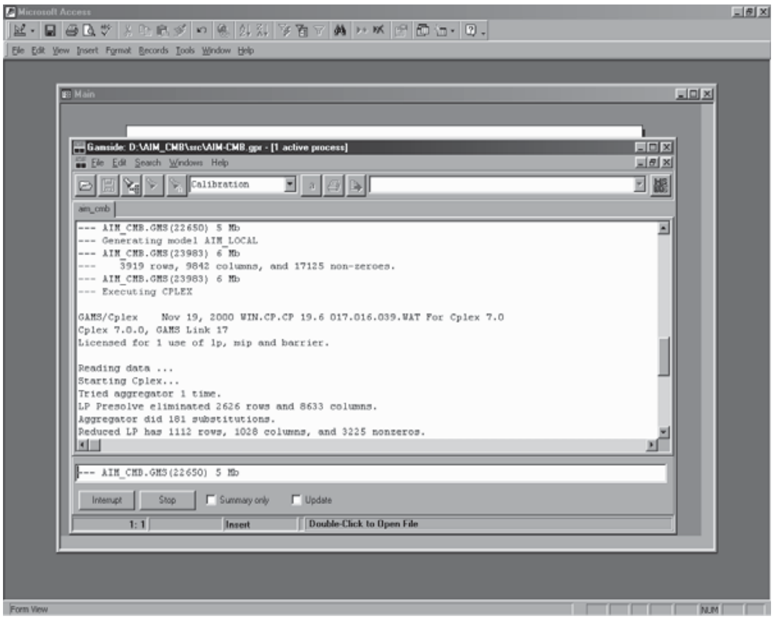

Fig. 2.3.6 How to implement AIM/Enduse GAMS version (3).

2.3.3 How to import output file of AIM/Enduse GAMS version

After implementation of simulation, the database system imports the output file of AIM/Enduse GAMS version. If user clicks on “Converting data from GAMS”, the database system starts to import data from output file of AIM/Enduse GAMS version. After importing, the message appears as shown in Fig. 2.3.7.

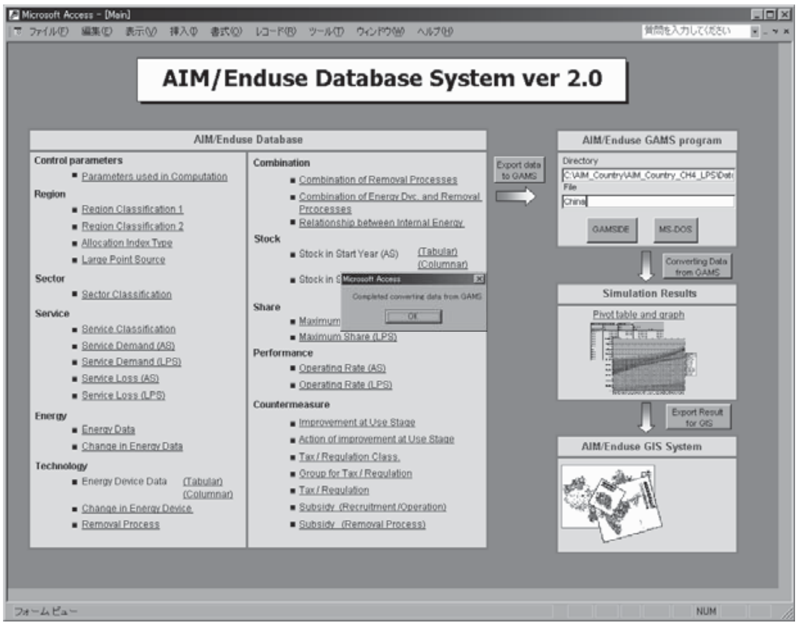

Fig. 2.3.7 How to import output file of AIM/Enduse GAMS version.

2.3.4 How to display simulation results

AIM/Enduse database system displays simulation results with pivot table after importing data from output file of AIM/Enduse GAMS version. If user clicks on “Display simulation result”, the form as shown in Fig. 2.3.8 appears. After simulating with AIM/Enduse GAMS version, user must refresh data. For this the user must select ‘Table’ worksheet and click right button on mouse. Then select “Refresh Data” on the list as shown in Fig. 2.3.9.

Pivot table and chart allows the user to create dynamic summary data. For example, if user clicks the filter on the upper side of the form as shown in Fig. 2.3.10, it shows the list. If user selects ‘EMS’, it shows emission results. Pivot table shows the result freely and easily with selecting the combination of items on the list of the filter (Table 2.3.1).

Table 2.3.1 Filter of pivot table

Filter		Choice	Content
Kind		EMS	Emission quantity (I,M,L,P,Y)
		ENG	Energy consumption (I,K,L,P,Y)
		SRV	Service supply (I,J,L,P,Y)
		STK	Stock quantity (I,L,P,Y)
		CST	Item = RCA, RCI, MDA, MDI
		RCT	Recruited amount (I,L,P,Y)
		DEV	Operating quantity (I,L,P,Y)
Item	Kind = EMS(M)	(Gas Type)	The gas code in “Parameters used in computation”
	Kind = ENG(K)	(Energy Type)	The energy code in “Energy Classification”
	Kind = SRV(J)	(Service Type)	The service code in “Service Classification”
	Kind = STK	-	-
	Kind=CST	RCA	Total annualized investment cost(I,L,P,Y)
		RCI	Total initial investment cost(I,L,P,Y)
		MDA	Total annualized cost of exchanging removal process (I,L,P,Y)->(I,L,P1,Y)
Item	Kind = CST	MDI	Total initial cost of exchanging removal process (I,L,P,Y)->(I,L,P1,Y)
		MNT	Total operating cost including energy cost, material cost, maintenance cost etc.(I,L,P)
		TXE	Energy tax payment (I,L,P)
		TXM	Emission tax payment (I,L,P)
LPS_Area		LPS	Large point source
		Area	Area source
Region (I)		(Region 1)	The code you input in “Region Classification 1”
LPS (I)		(LPS)	The code you input in “LPS”
Sector (I)		(Sector type)	The code you input in “Sector Classification”
Energy_device (L)		(Energy device)	The code you input in “Energy Device Classification”
Removal (P)		(Removal process)	The code you input in “Removal Process”

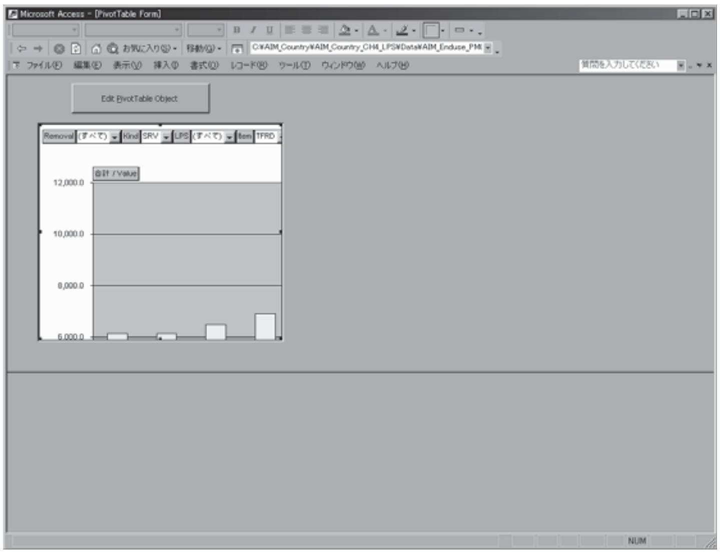

Fig. 2.3.8 How to display simulation result (1).

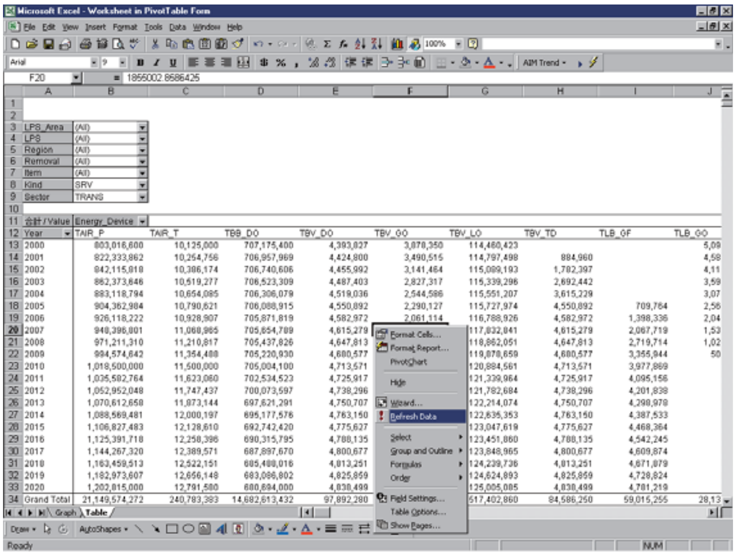

Fig. 2.3.9　How to display simulation result (2).

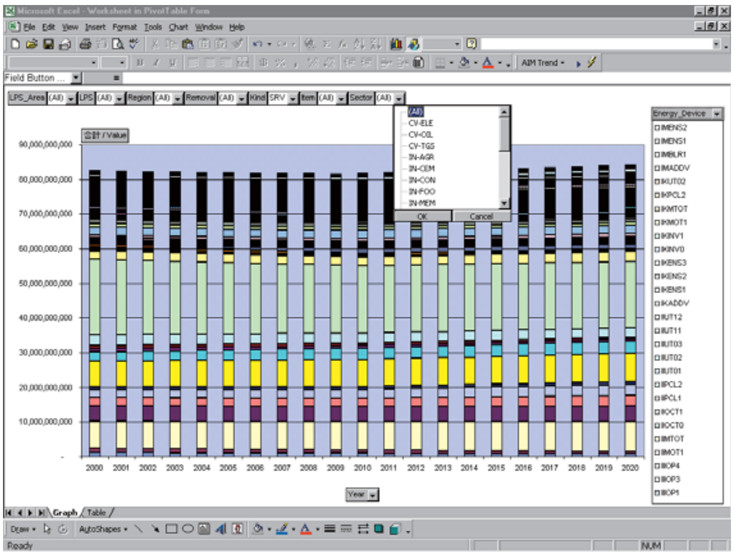

Fig. 2.3.10　How to display simulation result (3).

3. How to develop AIM/Enduse input

3.1 Choice of start year, end year, and discount rate

Following data are required to be entered in AIM/Enduse for the start year of calculation – Service demand (for each service kind), Specific service output, Specific energy input, Operating rate, Fixed cost, Operational cost, Stock, Share and Emission coefficient (for each device), Price and Emission coefficient (for each energy kind). Start year should be the latest year for which the above-mentioned data are either directly available from published sources or easily estimated by the user team using the methodology described in section 3.4 of this chapter. It is advised that user teams select 2000 as reference year. However, if required data are not available for 2000, then reference year should be the latest year for which data are available. This should be updated to 2000 once updated statistics are available.

The choice of end year of calculation should depend on the trade-off between i) the need for long term perspective required for GHG mitigation policy analysis, and ii) the level of confidence that the user team can place in long-term projections of service demands and characteristics of future technologies. Most energy optimization models for analyzing technological options for GHG mitigation have 30-50 year horizon. For application of AIM/Enduse, a time horizon extending up to at least 2032 is recommended, since it coincides with Rio+40.

Each year in AIM/Enduse can be treated as either calendar year or financial year. This choice should depend on the definition of year adopted in the majority of sector-level publications of data that the user team refers to from within a country.

3.2 Classification of region, energy, sectors and services

Region classification is not used in current version of AIM/Enduse model. Only one region, i.e. the country for which the model is to be set up, is considered.

Classification of energy should be based on standard classification used in IEA Energy Balance Tables or IPCC documents. Appendix F lists a standard classification of energy, calorific values, emission coefficients, and prices.

Choice of sectors and services should depend on i) importance of a sector in national energy system, ii) importance of a service in its sector’s energy use, and iii) availability of data for service demand and technologies used for satisfying a service. Choice of unit of service demand should also depend on the availability of data. As far as possible, the unit of service demand should be such that it is a measurable representation of the service being provided. Appendix E gives two possible classifications of sectors and services. Exact classification adopted by the user team should depend on its own judgment.

3.3 Classification and definition of technologies

3.3.1 Energy device

The extent of detail while classifying the devices should depend on the availability of technology level data from published sources. In AIM/Enduse, a technology is represented in terms of a single device or a sequence of multiple devices. Each device is identified by its energy and material inputs and service outputs. A device can have multiple inputs and multiple outputs. Appendices J and L show examples of technologies as represented in AIM-India and AIM-Japan respectively. Technologies of most industrial processes can be represented in terms of sequence of multiple devices. Such disaggregated representation of technologies allows the user to introduce improvement options at each distinct device or stage of operation.

3.3.2 Removal process

This classification can be based on standard removal processes available in industries for reducing SO_2 or NO_x emissions. SO_2 removal processes can be broadly categorized as coal washing (pre-combustion stage), limestone addition (in-situ combustion stage), and flue gas desulfurization (post-combustion stage) technologies. NO_x removal processes can be broadly categorized as removal technologies used for stationary sources of emission like power plants, industrial boilers and furnaces, and those used for mobile sources of emission like transport vehicles.

3.4 Estimation of data for start year

3.4.1 Estimation of service demands

Data for service demands in start year should be obtained from published sources. Reliable domestic sources of information (e.g. publications by ministries, government agencies, industry associations, independent research organizations) should be preferred over international sources.

Choice of units for service demands is important. While on one hand the unit of a service demand should represent a good measure of the service, on the other hand it should be convenient from the point of estimating data (see Appendix E for possible choices of units). In case the data for a service demand is not available in desired unit, then either it should be converted to desired unit or the unit of service demand should be changed. Reasonable assumptions need to be made for conversion of data to desired unit. Table 3.4.1 shows some examples of methodology for conversion of data.

Table 3.4.1 Examples of methodology for conversion of service demand data in desired unit

Ex. no.	Service	Desired unit A	Unit in which data is available B	Additional assumptions required	Expression for conversion to desired unit
1	Road passenger transport	Person-km	Vehicle-km	C = Average persons per vehicle	A = B * C
2			Bi = Vehicle-km in vehicle category i	Ci = Average persons per vehicle in category i	A = ∑ (Bi * Ci)
3			Bi = No. of vehicles in category i	Ci = Average persons per vehicle in category i Di = Average yearly km traveled by a vehicle in category i	A = ∑ (Bi * Ci * Di)
4	Residential cooking	Kgoe of useful energy service for cooking	Bi = Kgoe of energy used by stoves of type i	Ci = Average efficiency of stoves of type i	A = ∑ (Bi * Ci)
5			No. of households	C = Kgoe of daily useful energy service required for cooking by a typical household	A = B * C
6	Residential lighting	Lumen-hr	Bi = KWh of electricity used by lamp of type i	Ci = Lumens of light delivered by lamp of type i Di = Watt rating of lamp of type i	A = ∑ {Bi * (Ci / Di) * 1000}

Note: These are mere examples; Exact methodology for estimating a particular service demand will depend on the specific data that are available to the user team.

3.4.2 Estimation of data for devices

Following data are required by AIM/Enduse for each technology in the start year: Fixed cost, Operational cost, Life, Specific service output, Specific energy input, Stock, Share, Operating rate, and Emission coefficients (for SO_2 and NO_x). These data should be estimated based on a combination of following steps:

1. Obtaining data from published sources: Often, all the data required for AIM/Enduse can not be obtained directly from published sources.
2. Using standard assumptions about efficiency, cost, and other parameters: Such assumptions should be made if all the data can not be obtained from published sources. Appendices F, K and M provide some standard assumptions for selected technologies.
3. Final estimation using bottom-up accounting approach: Final estimation of data required by AIM/Enduse should be made using both the data obtained from published sources and the standard assumptions, and making sure that fundamental relationships between different parameters are not violated. Table 3.4.2 shows some examples of this methodology.

Table 3.4.2 Examples of methodology for estimation of device data in start year

Ex. no.	Parameters for which data or standard assumption are available	Desired unit of device	Additional assumptions required	Estimation of parameters required by AIM/Enduse: Specific service output	Specific energy input	Stock	Share
1	Ai = Population (no. of physical units) of device i, for all devices satisfying a particular service Bi = Quantity of service output delivered per unit input of fuel k by device i	One physical unit of device	Ck = Calorific value of fuel k Di = Average activity of one unit of device i in a year (unit of this may be hours, or service output delivered) Ei = Amount of fuel k used by a unit of activity of device i	Bi * Di * Ei	Di * Ei * Ck	Ai	Ai * Bi * Di * Ei / ∑ (Ai * Bi * Di * Ei)
2	Ai = Service output delivered in a year by device i Bi = Quantity of service output delivered per unit input of fuel k by device i	One physical unit of device	Ck = Calorific value of fuel k Di = Activity of one unit of device i in a year (its unit may be hours, or service output delivered) Ei = Amount of fuel k used by one unit of activity of device i	Bi * Di * Ei	Di * Ei * Ck	Ai / (Bi * Di * Ei)	Ai / ∑ Ai
3	Ai = Amount of fuel k used in a year by device i Bi = Quantity of service output delivered per unit input of fuel k by device i	One physical unit of device	Ck = Calorific value of fuel k Di = Activity of one unit of device i in a year (its unit may be hours, or service output delivered) Ei = Amount of fuel k used by one unit of activity of device i	Bi * Di * Ei	Di * Ei * Ck	Ai / (Di * Ei)	Ai * Bi / ∑ (Ai * Bi)
4	Ai = Amount of fuel k used in a year by device i Bi = Quantity of service output per unit input of fuel k by device i	One unit of service output of device	Ck = Calorific value of fuel k	1	(1 / Bi) * Ck	Ai * Bi	Ai * Bi / ∑ (Ai * Bi)
5	A = Total energy used in a year by all devices satisfying a particular service Bi = Quantity of service output delivered per unit input of fuel k by device i	One unit of service output of device	Ck = Calorific value of fuel k Di = Share of device i in total energy used A	1	(1 / Bi) * Ck	Bi * Di * Ai / Ck	(Bi * Di * Ai / Ck) / ∑∑ (Bi * Di * Ai / Ck)

Note:

i) These are average estimates for each classification of device. If the user selects aggregate classification of device that in reality comprises multiple types of devices with different characteristics, then average data for the aggregate classification must be entered in 'Stock' table and data for most recent or efficient type of device in that classification must be entered in 'Device' table. Data for both aggregate classification of device and specific type of device can be estimated using methods described in this table.

ii) Estimates for Fixed cost, Operational cost, and Life of a technology can be directly obtained from published sources like manufacturers' manuals.

iii) These are mere examples; Exact methodology estimating a particular technology's parameters will depend on the specific data that are available to the user team.

3.4.3 Estimation of data for removal processes

Appendix J briefly outlines the methods used for estimation of characteristics of some standard removal processes used in power plants, industries and transport sector. It also provides estimates for these processes.

3.5 Projection of service demands

It must be realized that long-term demand projections may not be accurate. Therefore, it is recommended that in addition to selecting a forecasting methodology that incorporates most determinants of service demands, users must also consider multiple demand scenarios in order to assess robustness of model results to accuracy of demand projections. Several alternative approaches exist for projecting service demands over 30-50 years. We briefly describe some general approaches below.

3.5.1 Obtaining projections from authoritative sources

User team should first obtain projections of service demands from authoritative sources like governmental five-year plans or expert estimates. Often projections for all service demands cannot be obtained from such sources. Moreover, projections available are typically for near-term and not for 30-50 years. In some cases, assumptions about growth rates may be made based on near-term projections.

3.5.2 Using a quantitative method to project service demands

A wide spectrum of quantitative methods can be used for long term projection of service demands. Complexity and data requirement of methods vary widely in this spectrum. On one end, complex models like CGE (e.g. AIM/CGE) that model the structure of an economy, can be adopted. On the other end, statistical methods like linear regression, or non-linear regression using an exponential or polynomial function, can be adopted.

While using such methods the user may sometimes project a service demand as a function of ‘drivers’. Table 3.5.1 lists examples of drivers for various services. Choice of method and drivers is often restricted by the availability of time-series data. Judgment of user team is crucial in selecting the method and drivers.

Table 3.5.1 List of possible drivers for service demands

Service	Driver
Services in agriculture sector	GDP; Gross physical output of agriculture; Gross monetary output of agriculture; Irrigated area
Services in transport sector	GDP; Gross monetary output of transport
Road transport services	Length of roads; Road vehicles per km road
Road passenger transport service	Private vehicles per capita
Rail transport services	Length of railway tracks; Rail traffic per km
Freight transport services	Revenue from freight transport
Services in residential sector	Private final consumption expenditure; Number of households; Income per household;
Services in urban residential sector	Number of urban households; Income per urban household
Services in rural residential sector	Number of rural households; Income per rural household
Services in commercial sector	GDP; Gross monetary output of commercial services
Services in restaurants / hotels	Value added / employment in restaurants / hotels
Services in hospitals / clinics	Value added and employment in hospitals / clinics
Services in corporate and government offices	Value added in corporate and government offices
Services in industrial sector	GDP; Industry value added
Services in a particular industry	Gross monetary output of a industry

Examples of methodologies for projection of demands adopted in case of India and Japan are illustrated in chapters 4 and 5 respectively. It must, however, be noted that these are mere examples and not necessarily the most desirable approaches in the context of a particular country.

3.6 Projection of improvement in devices

Improvements in efficiency, cost and emission coefficient of a device occur over time due to several factors including ‘learning-by-doing’ and ‘economies of scale’ effects. Following are some examples of approaches that can be used for these projections:

3.6.1 Obtaining improvement targets from authoritative sources

Sometimes near-term improvement targets can be found in publications of sectoral plans by governments/government-agencies.

3.6.2 Top-runner methodology

An approach popularly known as ‘top-runner’ methodology in Japan, assumes that the ‘best’ performing technology in a particular year will become ‘average’ performing after a certain period of time. This period of time can vary from 2-5 years in case of a rapidly growing industry in a growing economy to 10-20 years in case of a matured industry in a slow economy. Judgment of user team is crucial in making these assumptions.

3.6.3 Assuming fixed rates of improvement

Fixed rates of improvement can be assumed for each technology based on recent trends and considering efficient technologies from developed countries as benchmarks. Appendix I provides characteristics of technologies in AIM-Japan including advanced technologies in Japan.

3.7 Projection of maximum share of devices

Ideally, maximum share of a device should be 100% from the year of its introduction. This implies that service demand in a given year will be met by most economic devices (with least annualized capital cost and running cost for newly recruited devices, and least running cost for old devices). However this phenomenon is not fully observed in reality especially in developing economies.

In the past, several socio-economic-institutional barriers existing in developing countries have prevented early penetration of efficient devices. Although this situation is changing with ongoing economic reforms, several barriers continue to exist. Therefore, upper bounds on penetration of new and future technologies need to be introduced in different sectors. User teams should use their understanding of the domestic socio-economic-institutional context and opinions of experts to decide upper bounds on future share on devices.

Several factors that are not incorporated in costs, play crucial role in determining competitiveness of technologies in certain markets even in developed countries. For example, reliability of performance during use, service quality including perceived quality, effectiveness of delivery and maintenance services, and constraints of production or delivery capacities, are among such factors. User teams are advised to consider all such factors while applying upper bounds on shares of technologies.

In addition to projecting maximum shares under business-as-usual scenario, user teams should build additional scenarios based on different forecasts about progress of economic and institutional reforms in future.

Appendix A. Exercise

A.1 Estimate future emission from passenger car

A.1.1 Purpose

- Learn how to develop data for AIM/Enduse.
- Learn how to estimate future emission with the following countermeasures.
  - Countermeasure at use stage
  - Carbon tax
  - Subsidy

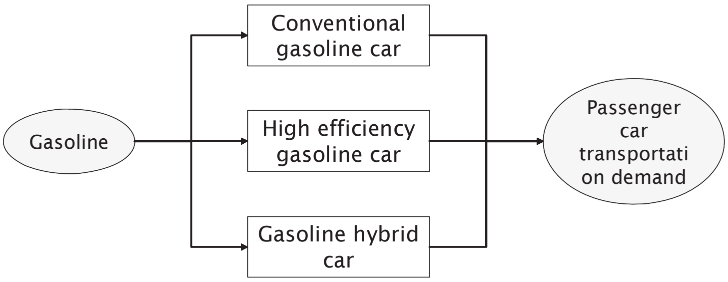

Fig. A.1 Technology system of Exercise 2.

A.1.2 Assumptions

A) Transportation demand

Table A.1 Transportation demand

		2000	2010	2030
TPRC	Passenger Car demand (10^3km)	120,000,000	200,000,000	300,000,000

B) Stock number of conventional gasoline car in 2000

Table A.2 Stock number of conventional gasoline car in 2000

	2000
Stock number of conventional gasoline car in 2000	6,000,000

C) Energy devices specifications

Table A.3 Energy devices specifications

		Fuel efficiency (km/kg)	Life time	Price (US$)
TCG1	Conventional gasoline car	18	10	1,000
TCG2	High efficiency gasoline car	24	10	1,500
TCG3	Gasoline Hybrid car	36	10	2,000

D) Average usage characteristics per car

Table A.4 Average usage characteristics per car

	2000-2030
Average number of persons per car	2
Average km travel per car per year	10,000

E) Energy Specification

Table A.5 Energy Specification

		Price ($/kg)
EL_OLG	Gasoline	0.4

Step1 Data Entry

Step1-1 Enter parameters in "Parameters used in computation"
- Start year = 2000
- End year = 2020
- Discount rate = 20%
- Unit price = US$
- Unit of Energy = GJ
- Unit of CO_2 = kg-C
- Unit of SO_2 = kg-SO_2
- Unit of NO_x = kg-NO2

Step 1-2. Enter country code and name in "Region Classification1"
- Enter your country code and name

Step 1-3. Enter sector code and name in "Sector Classification"
- Enter "TP-ROD" as sector code and "Transportation – Road" as sector name

Step 1-4. Enter service code, name and unit in "Service Classification"
- Refer assumption A)

Step 1-5. Enter service demand in "Service Demand (AS)"
- Refer assumption A)

Step 1-6. Enter energy specification in "Energy Data"
- Energy Price in assumption E) needs to be converted to match the unit in "Parameters used in computation". Refer Appendix F,G and calculate it.
- Find CO_2 emission factor and SO_2 emission factor from Appendix F

Step 1-7. Estimate the specification of energy device in "Energy Device Data"
- Specific energy consumption and specific service output need to be calculated from assumption C), D) and Appendix F
- Specific Service Output
= Average km traveled per car per year * Average number of persons per car
- Specific Energy Consumption
=Average km traveled per car per year / Fuel efficiency * calorific value

Step 1-8. Enter stock number in "Stock in Start Year"
Refer assumption B)

Step2 Simulation of reference case

Step 2-1. Click "Export data to GAMS"
Step 2-2. Execute AIM_CMB program
Step 2-3. Click "Conversion Data from GAMS"
Step 2-4. Click "Display simulation result"

Step3 Simulation of Improvement at use stage

Step 3-1. Enter countermeasure at use stage in "Improvement at use stage"
Step 3-2. Enter action rate in "Action of improvement at use stage"
Step 3-3. Calculate future emission

Table A.6 Improvement at use stage

		Fuel saving	Action rate		
			2000	2010	2030
T01	Driving with appropriate tire pressure	3.8%	10%	50%	100%
T02	Stop idling	3.0%	10%	50%	100%

Step4 Simulation of carbon tax

Step 4-1. Enter countermeasure type in "Tax/Regulation Classification"
Step 4-2. Select carbon tax in the list of group for CO_2 in "Group for Tax/Regulation Measure"
Step 4-3. Enter tax rate in "Tax/Regulation"
Step 4-4. Calculate future emission

Table A.7 Carbon tax

	2000-2002	2003-2020
Carbon tax	Without tax	1.0US$/kg-C

Step5 Simulation of subsidy

Step 5-1. Enter subsidy rate in "Subsidy (Recruitment/Operation)"
Step 5-2. Calculate future emission

Table A.8 Subsidy

	2000-2002	2003-2020
Subsidy	Without subsidy	30% subsidy for recruitment of gasoline hybrid car

A.2 Estimate future emission from power generation

A.2.1 Purpose

- Learn how to combine energy device with removal process
- Learn how to estimate future emission with the following countermeasures.
  - SO_2 emission regulation
  - CO_2 emission regulation

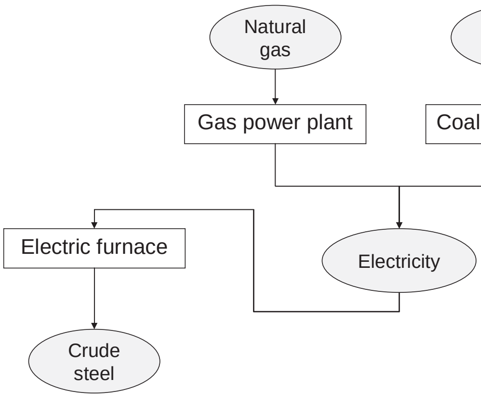

Fig. A.2 Technology system of Exercise 3.

A.2.2 Assumptions

A) Crude steel production demand

Table A.9 Crude steel production demand

		2000	2010	2030
STL	Crude steel production (t)	10,000,000	15,000,000	30,000000

B) Energy devices specifications

Table A.10 Energy devices specifications

		Capacity	Price	Energy efficiency	Life time
ELSTL	Electric furnace	500,000 t/year	25 Million US$	250 Million kWh/yr.	40
PWCL	Coal power plant	1,000,000 kW	3,000 Million US$	40%	40
PWNG	Gas power plant	1,000,000 kW	3,000 Million US$	50%	40

C) Stock quantity and operating rate of energy device

Table A.11 Stock quantity and operating rate of energy device

		Stock	Operating rate
PWCL	Coal power plant without desulfurization	1,000,000kW	57.1%
PWCL	Coal power plant with desulfurization	0	57.1%
PWNG	Gas power plant	0	57.1%
ELSTL	Electric furnace(500,000t/year scale)	20	100%

D) Energy specifications

Table A.12 Energy specifications

		Price
EN_COL	Coal	0.05$/kg
EN_GNG	Natural gas	0.2$/Nm3

E) Removal process

Table A.13 Removal process

		Stage of process	Removal rate(%)	Initial cost ($/GJ)	Operating cost ($/GJ)	Additional energy use
SHWF3	FDG Hard coal	Post-combustion	95%	3.53	0.19	0.9%

Step1 Data Entry

Step1-1 Enter parameters in “Parameters used in computation”

- Start year = 2000
- End year = 2020
- Discount rate = 20%
- Unit price = US$
- Unit of Energy = GJ
- Unit of CO_2 = kg-C
- Unit of SO_2 = kg-SO_2
- Unit of NO_x = kg-NO2

Step 1-2. Enter country code and name in “Region Classification1”

- Enter your country code and name

Step 1-3. Enter sector code and name in “Sector Classification”

- Enter “IN-STL” as sector code and “Industry - Steel” as sector name
- Enter “CV-ELE” as sector code and “Power generation” as sector name

Step 1-4. Enter service code, name and unit in “Service Classification”

- Refer assumption A)
- Add Electricity (Code: EN_ELE, Unit: GJ)

Step 1-5. Enter service demand in “Service Demand (AS)”

- Refer Assumption A)
- Service demand of EN_ELE is calculated endogenously, so Enter 1 as the service demand of EN_ELE

Step 1-6. Enter energy specification in “Energy Data”

- Energy Price in assumption D) needs to be converted to match the unit which you entered in “Parameters used in computation”. Refer Appendix F,G and calculate it.
- Find CO_2 emission factor and SO_2 emission factor from Appendix F

Step 1-7. Estimate the specification of energy device in “Energy Device Data”

- Specific energy consumption and specific service output need to be calculated from assumption B), C) and Appendix G
- Enter “1kW” as unit of coal power plant and gas power plant
- Enter “500kt” as unit of electric furnace

Step 1-8. Enter removal process data in “removal process”

- Refer assumption E)

Step 1-9. Enter combination of removal process in “combination of removal process”
- Select “SHWF3” as post combustion and enter “SHWF3” as code of combination of removal processes

Step 1-10. Enter combination of energy device and removal process in “combination of Energy Dvc. and removal processes”
- Set combination of coal power plant and removal process

Step 1-11. Enter relationship of internal energy in “Relationship between Internal Energy/Service”
- Select “EN_ELE” as both internal energy and internal service

Step 1-12. Enter stock number in “Stock in Start Year”
- Refer assumption C)

Step 1-13. Enter operating rate in “Operating rate”
- Refer assumption C)

Step2 Simulation of reference case

Step 2-1. Click “Export data to GAMS”
Step 2-2. Execute AIM_CMB program
Step 2-3. Click “Conversion Data from GAMS”
Step 2-4. Click “Display simulation result”

Step3 Simulation of SO_2 regulation

Step 3-1. Enter countermeasure type in “Tax/Regulation Classification”
Step 3-2. Select SO_2 regulation in the list of group for CO_2 in “Group for Tax/Regulation Measure”
Step 3-3. Enter maximum limit in “Tax/Regulation”
Step 3-4. Calculate future emission

Table A.14 SO_2 regulation

	2000-2020
Regulation	20,000,000kg-SO_2

Step4 Simulation of CO_2 regulation

Step 4-1. Enter countermeasure type in “Tax/Regulation Classification”
Step 4-2. Select CO_2 regulation in the list of group for CO_2 in “Group for Tax/Regulation Measure”
Step 4-3. Enter maximum limit in “Tax/Regulation”
Step 4-4. Calculate future emission

Table A.15 CO_2 regulation

	2000-2020
Regulation	5,000,000,000kg-C

Appendix B. Illustration of AIM/Enduse Japan

B.1 Start year, end year and discount rate

Start year is chosen as 1998. Calibration for energy consumption and CO_2 emission is done for 2000. End year is chosen as 2020.

The discount rate is assumed as 30%. The questionnaire-survey we executed for companies and households in Japan showed that the payback period of energy saving technology was about three years. We set the discount rate so as to fit the rate on payback period.

B.2 Choice of sectors and services

B.2.1 Sectors

Following sectors are chosen for Japan:

Energy demand sectors. Industry (further divided into Steel, Cement, Petrochemicals, Paper, Agriculture, Mining, Construction, Food, Textile, Other chemicals, Other ceramics, Non Ferrous, Metal and Machinery, Other manufacture), Residential, Commercial and Transportation.

Energy production, conversion and supply sectors. Electricity generation, Oil refinery and Town gas.

B.2.2 Services in industrial sector

In steel, cement, petrochemicals and paper, the outputs of main products denoted by weight are used as final service. In other industries, value added denoted by monetary account is used as the final service.

B.2.3 Services in residential sector

25 types of services are chosen in residential sector. As for cooling, warming, hot water and lighting, effective (or useful) energy demand is used as the final service demand. The statistics of effective energy demand is not available. Therefore it is estimated by the method of dividing energy consumption by service efficiency. As for other types of services, mainly electric appliances, total number of holding is used as the index indicating final service demand. In case a service is denoted by total appliance holding comprising different sizes of appliances, unit of service demand is defined as number of appliances equivalent to a particular size. This particular size is normally the average size in the start year. If average size of appliances changes in future, the future demand is still expressed as number of appliances weighted with change of average size.

B.2.4 Services in commercial sector

15 types of services are chosen in commercial sector. As for cooling, warming and hot water, effective energy demand is used as the final service demand. Effective energy demand is estimated using same method as in the case of residential sector. As for other types of services, floor space area weighted with service intensity change is used as the measure of final service demand.

B.2.5 Services in transportation sector

10 and 9 types of services are chosen in passenger and freight transportation sectors respectively. Volume of transportation denoted by person-km and ton-km are used as the service demand in passenger and freight transportation sectors, respectively.

B.2.6. Services in energy conversion sector

Demand for electricity, oil products and town gas are used as the final service demand, respectively.

B.3 Estimation of energy data

B.3.1 Energy price

Fuel import price. Crude oil import CIF (cost including insurance and freight) price in 2010 is quoted from the estimate by METI (2001). As for the price after 2010, it is assumed that the trend from 2000 to 2010 would continue until 2020. LNG price would be linked with crude oil price. The rate of increase in coal price would be half of that in oil price.

Secondary energy price. The elasticity between crude oil price and secondary energy price without tax is estimated from EDMC (2001) data for the past 15 years. Then the future price of oil products is estimated from the elasticity and the future crude oil price. Finally nominal price is converted to real one with 1% deflator.

B.3.2 Emission factor

CO_2 emission factors estimated by Ministry of Environment for Japan's National Communication are used in AIM-Japan. Factors for coal and oil products are estimated based on weighted averages.

SO_2 emission factors estimated in Japan's National Communication are used in AIM-Japan. N-content of fuel is assumed to be zero. The NO_x emission, which originates due to interaction of air with combustion, is listed by energy device.

Table B.1 Classification of sectors and services in AIM-Japan

Sector and Final Service	Service Unit	Sector and Service	Service Unit
Industry - Steel		Commercial	
Hot rolled products	Tons	Cooling	10^5 kcal
Cold rolled products	Tons	Warming	10^5 kcal
Industry - Cement		Hot water (town gas area)	10^5 kcal
Cement	Tons	Hot water (LPG area)	10^5 kcal
Portland clinker for export	Tons	Cooking	$100m^2$
Industry - Petrochemistry		Lighting(fluorescent)	$100m^2$
Ethylene	Tons	Lighting(incandescent)	$100m^2$
Low density polyethylene	Tons	Fire exit light	$100m^2$
High density polyethylene	Tons	Mainframe	$100m^2$
Polypropylene	Tons	Duplicator	$100m^2$
Polystylen	Tons	Elevator	$100m^2$
Industry - Paper		FAX	$100m^2$
Paper and Board	Tons	Personal Computer	$100m^2$
Industry - Others		Pumping power for AC	$100m^2$
Value added	Million yen	Others	$100m^2$
Residential		Transportation - Passengers	
Cooling	10^5 kcal	Mini-sized vehicle	100 prs.-km
Warming	10^5 kcal	Small-sized vehicle	100 prs.-km
Hot water (town gas area)	10^5 kcal	Regular-sized vehicle	100 prs.-km
Hot water (LPG area)	10^5 kcal	Commercial car	100 prs.-km
Lighting (fluorescent)	10^5 kcal	Private bus	100 prs.-km
Lighting (incandescent)	10^5 kcal	Commercial bus	100 prs.-km
Conventional refrigerator	Unit number	Private truck	100 prs.-km
Kotatsu	Unit number	Railroad	100 prs.-km
Fan	Unit number	Ship	100 prs.-km
Electric blanket	Unit number	Air	100 prs.-km
Electric fan heater	Unit number	Transportation – Freight	
Washing machine	Unit number	Mini vehicle (private)	100 ton-km
Vacuum cleaner	Unit number	Small vehicle (private)	100 ton-km
Microwave oven	Unit number	Regular vehicle (private)	100 ton-km
Clothing drier	Unit number	Mini vehicle (commercial)	100 ton-km
Electric carpet	Unit number	Small vehicle (commercial)	100 ton-km
TV	Unit number	Regular vehicle (commercial)	100 ton-km
VTR	Unit number	Railroad	100 ton-km
Stereo	Unit number	Ship	100 ton-km
Tape recorder-cum-radio	Unit number	Air	100 ton-km
Desktop personal computer	Unit number	Electricity generation	
Note personal computer	Unit number	Electricity	10^5 kcal
Word processor	Unit number	Oil refinery	
Toilet bow with warm water cleaner	Unit number	Oil products	10^5 kcal
		Town gas	
Other electricity use	Household	Town gas	10^5 kcal

Table B.2 Energy price in AIM-Japan (nominal)

Energy Type	Unit	1990	1995	2000	2010	2020
Crude oil	$/Barrel	23	18	27	30	35
Coal	$/t	51	50	35	36	40
LNG	$/t	23	18	27	30	35
Gasoline	Yen/l	122	107	119	125	129
Diesel	Yen/l	72	71	85	89	93
Kerosene	Yen/l	45	40	51	55	59
Heavy oil (A)	Yen/l	35	24	36	40	44
Heavy oil (C)	Yen/l	26	16	27	32	36
LPG	Yen/kg	218	238	228	230	231
Electricity (Lighting)	Yen/kWh	25	25	26	26	27
Electricity (Power)	Yen/kWh	17	17	18	19	20
Electricity (Industrial Use)	Yen/kWh	13	13	14	15	15
Town Gas	Yen/Mcal	10	9	11	12	12

Table B.3 Emission factor in AIM-Japan

	Emission Factor		
	CO_2 (g-C/10^2Mcal)	SO_2 (g-SO_2/10^2Mcal)	NO_x (g-NO_2/10^2Mcal)
Coal	10,120	139	0
Coal Products	12,300	172	0
Crude Oil	7,811	15	0
Oil products	7,743	83	0
Gasoline	7,658	2	0
Naphtha	7,605	1	0
Jet fuel	7,665	22	0
Kerosene	7,748	1	0
Diesel	7,839	25	0
Heavy oil(A)	7,911	87	0
Heavy oil(C)	8,180	277	0
LPG	6,833	0	0
Natural gas	5,639	1	0
Town Gas	5,500	0	0

B.4 Classification and definition of technology systems

Appendix I shows the technology systems considered in AIM-Japan. The extent of detail or disaggregation while identifying the devices depends on the extent of device level data available from published sources. We briefly describe some characteristics of technology systems below.

B.4.1 Technology systems in industrial sector

As for steel, cement, petrochemicals and paper, we assume the typical manufacturing process based on material flows with internal products to combine energy devices. In case of other industrial sectors, it is difficult to assume typical manufacturing processes due to variety of processes and products. Therefore we illustrate the systems based on energy use in the other industrial sectors. Energy use is disaggregated into steam, direct heat, power and other uses, and energy devices are selected to fit the system.

B.4.2 Technology systems in residential and commercial sectors

Technology systems in residential and commercial sectors are rather simpler than industrial sector. Internal energy or service does not exist except electricity. Electricity obtained from purchase, co-generation or solar power is defined as endogenous electricity and energy devices, e.g. air conditioner, refrigerator and personal computer, use the electricity as input.

B.4.3 Technology system of transportation sector

Technology systems in transportation sector are also simple. Internal energy or service does not exist. Energy devices in this sector need only one type of energy and supply only one type of service.

B.5 Estimation of energy device data

B.5.1 Energy devices in industrial sector

Table B.4 shows examples of estimation of specific service output, specific energy consumption, cost and other data for DC electric furnace and high performance pulp washing device. They are substitutional energy saving devices for AC electric furnace in steel sector and conventional pulp washing device in paper sector, respectively. In case of DC electric furnace, energy saving quantity can be obtained from published sources, but specific energy consumption data does not exist. We estimated energy consumption from the data on service share and energy consumption of related process. Estimation of data for several energy devices in industrial sector requires this kind of method.

Table B.4 Estimation examples of energy device data in industrial sector of AIM-Japan

		ex.1) DC electric furnace	ex.2) High performance pulp dashing device
Data from published sources and assumption method			
A	Energy saving quantity per products	85 Mcal/t-steel	-
B	Energy consumption in related process	373 Mcal/t-steel ('90)	-
C	Service share of device ('90)	1 % ('90)	12% ('90)
D	Energy consumption per products	341 Mcal/t-steel	5 kWh/t-pulp
Final estimates used in AIM-Japan			
E	Service share of device ('98)	4 % ('98)	38% ('98)
F	Energy consumption per device unit	341 Mcal/t-steel	4 Mcal/t-steel
G	Service supply per device unit	Crude Steel 1 t	Pulp 1 t
H	Price per device unit	5250 yen/t-steel	3143 yen/t-pulp

ex.1) A : MITI (1997); B : MITI (1991); C, E : MOE (2001) ; D : Estimate from A,B,C; F : =E; H : Japan Iron and Steel Federation (1997)
ex.2) C, E, H : MOE (2001), EA; D : Quesionaire to Japan Paper Association; F : E*0.86

B.5.2 Energy devices in residential and commercial sectors

Table B.5 shows estimated specific service output, specific energy input, cost and other data for air conditioner with highest efficiency in 1999 and conventional refrigerator. Values for air conditioner are estimated from product brochure. Values for stove, fan heater and water heater are estimated similarly. On the other hand, in case of refrigerator, average energy consumption value from published statistics is used. Data for all the electrical appliances are estimated by the same method.

Table B.5 Estimation examples of energy device data in residential sector of AIM-Japan

		ex.1) Air conditioner (Highest Eff. in 2000)		ex.2) Conventional refrigerator
Data from published sources and assumption method				
A	Capacity	cool	2.8kW	-
		warm	4.2kW	
B	Operating hours per year	cool	551 hours	-
		warm	1,073 hours	
C	Efficiency	cool	5.42	-
		warm	5.99	
D	Demand of service which a device supplies	cool	37.8 Tcal	56.0 million
Final estimates used in AIM-Japan				
E	Service share of device		0%	100%
F	Service supply per device unit	cool	1,376 Mcal/yr.	1 household
		warm	3,876 Mcal/yr.	
G	Energy consumption per device unit		341 Mcal/yr.	721 Mcal/yr.
H	Price per device unit		290,000 yen	180,000 yen
I	Stock quantity of devices		0	56.0 million

ex.1) A,B,C,H: Product brochure; D: Estimate (cf. Chapter 5.6 of Part IV); F: A*B; G: F*C; I: D*E/F
ex.2) D: Estimate (cf. Chapter 6.6 of Part IV), G: MITI(1998); H: Product brochure, I: D*E/F

B.5.3 Energy devices in transportation sector

Table B.6 shows estimation of specific service output, specific energy consumption, cost and other data for small-sized passenger vehicle and regular-sized freight vehicle. As shown in the table, the Japan's average value from published statistics is used for specific energy consumption and specific service output of vehicle. In the case of advanced vehicles (ex. gasoline hybrid, CNG, fuel cell), the value is estimated from the product brochure.

Table B.6 Examples of estimating energy device data in transport sector of AIM-Japan

		ex.1) Passenger vehicle (Small-sized, Gasoline)		ex.2) Freight vehicle (Regular-sized, Diesel)	
Data from published sources and assumption method					
A	Transportation volume by service	631.5	10^9 Person-km	201.3	10^9 ton-km
		410.9	10^9 km	49.9	10^9 km
B	Stock by device type	26.0	Million	0.88	million
C	Stock share of device	62.7	%	100.0	%
D	Transportation volume by device type	396.0	10^9 Person-km	201.3	10^9 ton-km
		257.6	10^9 km	49.9	10^9 km
E	Energy consumption by device type	217.9	10^{12} kcal	129.0	10^{12} kcal
F	NO_x emission factor per energy use	0.17	g/km	3.61	g/km
Final estimates used in AIM-Japan					
G	Price per device	1,527	10^3 yen	4,600	10^3 yen
H	Service supply per device unit	15.2	10^3 person-km/yr.	227.6	10^3 ton-km/yr.
		9.9	10^3 km/yr.	56.5	10^3 km/yr.
I	Energy consumption per device unit	8.38	10^6 kcal/yr.	145.9	10^6 kcal/yr.
J	NO_x emission per device unit	1.68	kg/yr.	203.8	kg/yr.

ex.1,2) A, B, C, E: Estimate based on MOT(2000); D : A*C; F: NRI(1998); G: Product brochure; H: A/B; I: E/B; J: F*H

B.5.4 Energy devices in energy conversion sector

Table 5.7 shows estimation of specific service output, specific energy consumption, cost and other data for coal power plant and nuclear power plant. In case of coal power plant, Japan's average data from published statistics are used for specific energy consumption and specific service output of plant. Data for oil and gas plant are estimated by the same method.

Table B.7 Examples of estimating energy device data in conversion sector of AIM-Japan

		Unit	Coal power	Nuclear
Data from published sources and assumption method				
A	Electricity power generation	GWh	135,997	316,818
B	Installed capacity of generation	MW	24,511	44,917
C	Energy consumption	PJ	1,234	-
D	NO_x emission factor	kg/10^8kcal	71.0	-
E	Own use	-	5%	4.4%
F	Thermal efficiency		39.7%	
Final estimates used in AIM-Japan				
G	Fixed cost	1000yen/kW	289	430
H	Service supply per device unit	100Mcal/yr.	71.57	72.03
I	Energy consumption per device unit	100Mcal/yr.	180.4	
J	Stock quantity	kW	24,511	44,917
K	Operating rate	-	63.3%	84.2%

A, B, C: MITI(1998); D: Environmental Research and Control Center (2000); E: (Coal) Estimate based on the data from MITI(1998), (Nuclear) Estimate based the data from Federation of Electric Power Companies of Japan (2001); F: C/A; G: Estimate based on data from Nikkan Denki Tsushinsha, (2000); H: 365*24*860*(1-E); I: (Coal) 365*24*860/F , (Nuclear) 365*24*2250; J: B, K: A/(B*365*24)

B.6 Projection of service demands

B.6.1 GDP

GDP does not directly correspond to the service demand for energy device in AIM-Japan. But it is used to estimate various service demands. Economic Council estimated in 1999 that Japan's economic average growth rate would be about 2% per annum by 2010. This estimate is used in AIM-Japan. After 2010, we assume that the growth rate per capita will continue at same level.

Table B.8 Economic growth rate in Japan

	'91-'95	'96-'00	'01-'05	'06-'10	'11-'15	'16-'20
Economic growth rate	1.4%	1.0%	2.0%	2.0%	1.8%	1.6%

B.6.2 Population, Household

The projections of population and household are taken from National Institute of Population and Social Security Research (1997, 1998).

Table B.9 Population and household in Japan

		1990	1995	2000	2010	2020
Population	Million	123,611	125,570	126,892	127,623	124,133
Household	Million	40,670	43,900	46,407	49,142	48,853

B.6.3 Service demands in industrial sector 1 – Steel, cement, petrochemicals, paper

The output projection of crude steel and ethylene are taken from Meeting for the Study of Material Industrial Structure (1999). The output of hot / cold rolled products and other petrochemicals are assumed to increase at the same rate as crude steel and ethylene, respectively. As for cement, the rate of increase is assumed to be same as for crude steel. The total output of paper and board are assumed to increase at the same rate as in 1990's. After 2010, decrease of population is assumed to restrain the increase rate of paper and board demand.

Table B.10 Industrial production in AIM-Japan

Industrial Products	Unit	1990	1995	2000	2010	2020
Crude steel	Million ton	111.71	100.02	106.44	96.51	93.87
Hot rolled products	Million ton	80.57	71.34	75.69	68.63	66.75
Cold rolled products	Million ton	28.35	27.89	27.33	24.78	24.10
Cement	Million ton	86.85	91.50	81.06	80.53	78.33
Ethylene	Million ton	5.81	6.94	7.61	6.66	6.48
Low density polyethylene	Million ton	1.78	1.75	1.89	1.61	1.56
High density polyethylene	Million ton	1.10	1.24	1.25	1.13	1.10
Polypropylene	Million ton	1.94	2.50	2.72	2.28	2.21
Polystylene	Million ton	1.21	1.28	1.16	1.02	1.00
Paper and board	Million ton	28.09	29.66	31.83	33.74	35.57

B.6.4 Service demands in industrial sector 2 – Other industries

The GDP elasticity of value added by type of industry, "β" in the following equation, is estimated from the statistics, EPA(2000), in the 1990s. Then the future value added is estimated from the elasticity and the future GDP.

$$Y = \alpha X^{\beta} \tag{B.1}$$

Where,
Y: Value added by type of industry
X: GDP
β: Elasticity

Table B.11 Value added by type of industry in AIM-Japan

Type of industry	Unit	1990	1995	2000	2010	2020
Agriculture	Trillion yen	10.9	9.7	9.5	8.1	7.1
Mining	Trillion yen	1.1	0.9	0.9	0.8	0.7
Food	Trillion yen	12.3	12.8	12.7	13.4	14.0
Textile	Trillion yen	2.5	2.1	1.9	1.3	0.9
Paper	Trillion yen	3.4	3.1	3.0	2.7	2.3
Chemicals	Trillion yen	9.4	11.0	13.0	18.3	24.4
Oil and coal products	Trillion yen	4.1	3.7	4.4	4.7	5.0
Ceramics	Trillion yen	4.4	4.3	4.3	4.4	4.5
Steel	Trillion yen	7.1	6.4	5.8	5.3	4.5
Non ferrous	Trillion yen	2.4	2.3	2.3	2.7	3.1
Metal and machinery	Trillion yen	56.5	62.9	65.7	93.5	125.2
Other manufacture	Trillion yen	19.2	16.7	17.0	14.8	13.2
Construction	Trillion yen	43.4	44.8	44.2	45.0	45.6

B.6.5 Service demands in residential sector

As for cooling, warming, hot water and lighting in residential sector, the service demand is projected using following equation.

$$SRV_t = HH_t * (SRV_0 / HH_0) * SI_t \tag{B.2}$$

$$SRV_0 = \sum_l (ENE_{0,l} / EF_{0,l} * SH_{0,l}) \tag{B.3}$$

Where,
SRV_t = Service demand in time period t
HH_t = Household number in time period t
SI_t = Change of service demand intensity in time period t (1990’s value = 1.0)
$ENE_{0,l}$ = Energy consumption of all the stock of device *l* in 1990.
$EF_{0,l}$ = Average service supply per energy input of device *l* in 1990.
$SH_{0,l}$ = Service share of device *l* in 1990.

As for other services in residential sector, the service demand is projected using following equation.

$$SRV_t = HH_t * HR_t * IS_t \tag{B.4}$$

Where,
SRV_t = Service demand in time period t
HH_t = Household number in time period t
HR_t = Holding rate in time period t
IS_t = Index of size in time period t (1990’s value = 1.0)

B.6.6 Service demands in commercial sector

As for cooling, warming, and hot water in commercial sector, the service demand is projected using following equation. The projection of floor space is estimated with the GDP elasticity of 0.7.

$$SRV_t = FS_t * (SRV_0 / FS_0) \tag{B.5}$$

$$SRV_0 = \sum_l (ENE_{0,l} / EF_{0,l} * SH_{0,l}) \tag{B.6}$$

Where,

SRV_t = Service demand in time period t
FS_t = Floor space in time period t
$ENE_{0,l}$ = Energy consumption of all the stock of device *l* in 1995.
$EF_{0,l}$ = Average service supply per energy input of device *l* in 1995.
$SH_{0,l}$ = Service share of device *l* in 1995.

As for other services in commercial sector, the service demand is projected using following equation.

$$SRV_t = FS_t * SI_t \tag{B.7}$$

Where,
SRV_t = Service demand in time period t
FS_t = Floor space in time period t
SI_t = Change of service demand intensity in time period t (1990's value = 1.0)

B.6.7 Service demands in transport sector – Passenger and freight

The projection of transportation volume is based on the estimate made by Council for Transport Policy (2000). Although the service classification of automobile is set by size in AIM-Japan, the projections are given by rough classification. Therefore projection for each service demand is derived by assuming the shares in 1998.

B.6.8 Service demands in energy conversion sector – Electricity generation, oil refinery and town gas

The service demands in energy conversion sector are the total demands for electricity, oil products and town gas in all the end-use sectors.

B.7 Case Study of AIM-Japan

B.7.1 Design of scenarios

Simulations are performed for the following three scenarios (cases):

- *Fixed case*: Current technologies continue to be selected because of a lack of understanding and/or for social reasons, even though there are economic benefits in changing the technologies. No countermeasures such as carbon / energy taxes or subsidies are assumed.
- *Market case*: Technology selection is based solely on a reasonable policy of economic efficiency.
- *Tax case*: A carbon tax is introduced beginning in 2001. 30,000 yen per ton of carbon is imposed on secondary fuels. As for electricity, energy tax is imposed at the same level as carbon tax.
- *Tax + Lifestyle change case*: Change of lifestyle for energy consumption is assumed in addition to a carbon tax. Concretely, the countermeasures shown in table B.12 are considered. The existing implementation rate is based on the questionnaire-survey of the general public in Aichi prefecture. We assume that all the countermeasures will be completely implemented in 2010 due to lifestyle change.

Table B.12 Countermeasure at used stage through lifestyle change in AIM-Japan

Countermeasures	Reduction rate of energy consumption	Existing implementation rate
1 degree reduction in temperature setting of air conditioner (heat)	3.00%	24%
1 degree increase in temperature setting of air conditioner (cool)	5.00%	24%
Cut down turning on lights	10.00%	40%
Reduction in hot water	5.00%	15%
Use refrigerator efficiently	5.00%	17%
Setting temperature to a more appropriate one	10.00%	42%
Turn off lights during lunch	5.00%	40%
Removal of any unnecessary luggage prior to driving	0.40%	27%
Driving with appropriate pressure	3.80%	40%
Stop idling	3.00%	33%

B.7.2 Results of the simulations

Fig. B.1 shows CO_2 emissions under four cases. CO_2 emission of fixed case would increase by 17% in 2010 and 21% in 2020 compared to 1990. Driving force in residential and transportation sectors will not expand after 2010 due to decrease of population in Japan. That is why increase of CO_2 emission is not significant after 2010. Under the condition of market case, increase in rate of CO_2 emission is 4% in 2010 and 0% in 2020 compared to 1990. Guideline for Measures to Prevent Global Warming was concluded in 2002 so as to achieve the target of Kyoto Protocol in Japan. The guideline provided the target of CO_2 emission originated from fuel combustion. The target is that the emission in 2010 should be at the same level as in 1990's. The result of market case shows that this target would be achieved without countermeasures. CO_2 emission in tax case would decrease by 1% in 2010 and 3% in 2020 compared to 1990. The result shows that carbon tax is a useful policy option to achieve the target of Kyoto Protocol. Moreover, the last case shows that lifestyle change would cause an additional 1% of CO_2 reduction.

Fig. B.2 shows SO_2 and NO_x emission. SO_2 emission, like CO_2 emission, would also decrease sufficiently in market case and tax case. On the other hand, NO_x emission would not decrease sufficiently. Fig. B.3 and B.4 show sector-wise CO_2 and NO_x emissions, respectively. The structures of emission differ vastly. NO_x emission in transportation sector shares large part of total NO_x emission. Hybrid and fuel cell vehicles which reduce both NO_x and CO_2 emissions would not be adopted even with carbon tax due to high installation costs. Lean-burn engine which would be economically efficient option to reduce CO_2 emission under the tax case is always not useful to reduce NO_x emission. That is why NO_x emission would not decrease in the tax case.

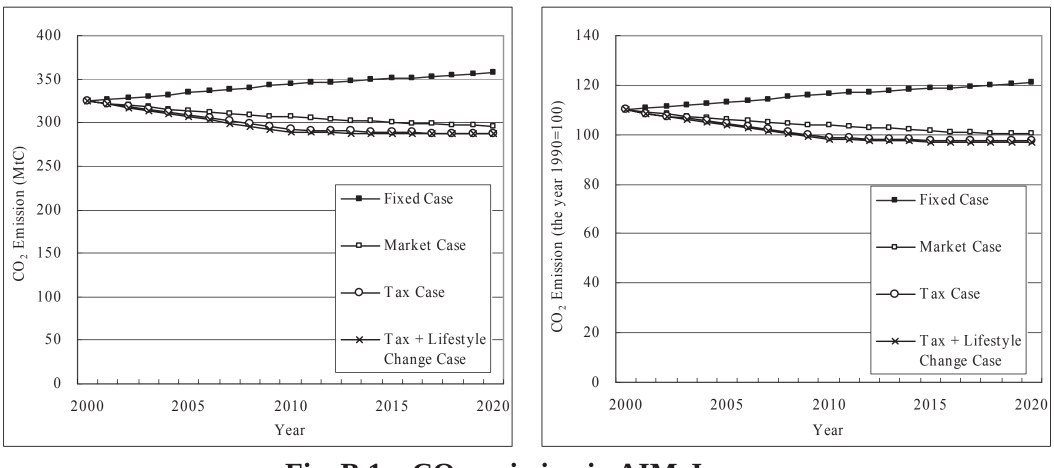

Fig. B.1 CO_2 emission in AIM-Japan.

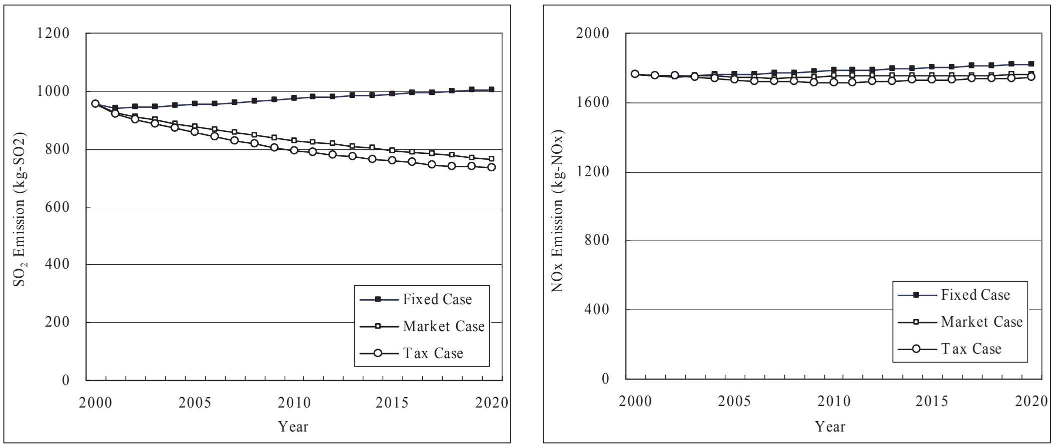

Fig. B.2 SO_2 and NO_x emission in AIM-Japan.

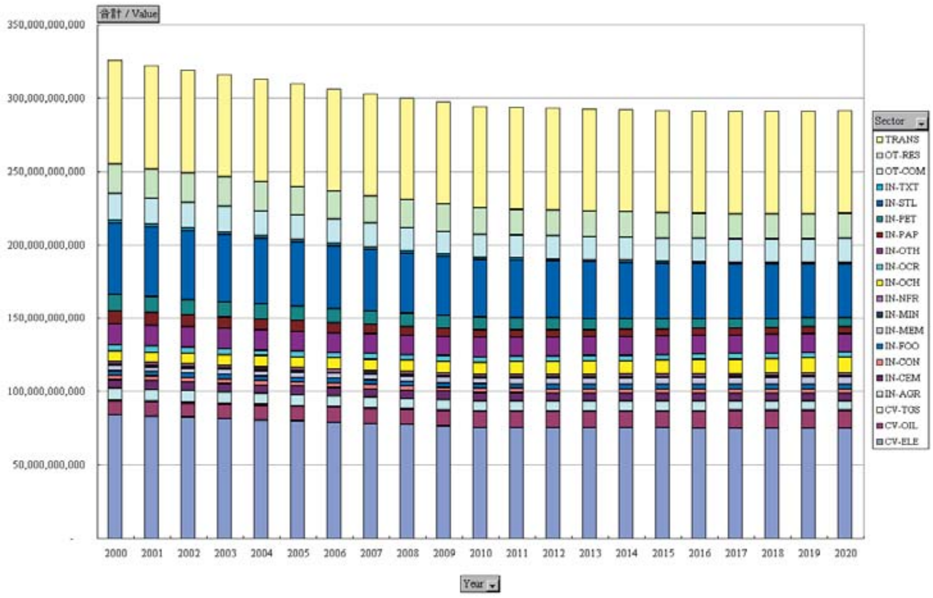

Fig. B.3 Sector-wise CO_2 emission in AIM-Japan.

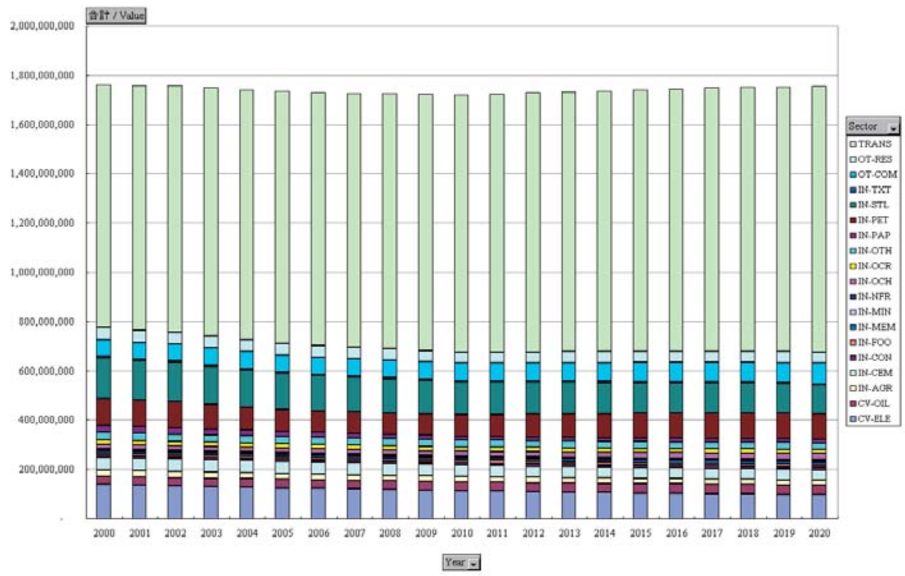

Fig. B.4 Sector-wise NO_x emission in AIM-Japan.

Appendix C. Theoretical formulation

C.1 Indices and sets

i	Sector
j	Service kind
k	Energy kind
l	Device
m	Gas (emission) kind
p	Gas (emission) removal process
W_j	Set of combinations of device and removal process *(l, p)* that can satisfy service kind j
z	Index denoting group of sectors categorized for the purpose of emission control
R_z	Set of sectors belonging to group z
G_i	Group of sectors selected for representing energy constraint
e	Index denoting group of sectors categorized for purpose of energy supply
R_e	Set of sectors belonging to group e
$V_{j,k}$	Set of internal service kinds j corresponding to internal energy kinds k (i.e. all k belonging to this set must be supplied by all j belonging to this set)

C.2 Formulation

C.2.1 Expression for Emission Quantity Estimation

Emission quantity of a gas is estimated adding up quantity of emissions from all devices. Emission from a device is estimated by multiplying operating quantity of the device with emission quantity per unit of device.

$$Q_i^m = \sum_j \sum_{(l,p)\in W_j} \left(X_{l,p,i} \cdot e_{l,p,i}^m \right) \tag{C.1}$$

$$e_{l,p,i}^m = \left(f_{0,l}^m + \sum_k f_{k,l}^m \cdot \left(1 - \xi_{k,l,i}\right) \cdot E_{k,l,p,i} \cdot U_{k,l} \right) \cdot d_{l,p,i}^m \tag{C.2}$$

Where,

Q_i^m: Emission of gas m in sector i

$e_{l,p,i}^m$: Emission of gas m from an operating unit of combination of device l with removal process p in sector i

$X_{l,p,i}$: Operating quantity of combination of device l with removal process p in sector i

$E_{k,l,p,i}$: Energy use of energy kind k per operating unit of combination of device l with removal process p in sector i (same as specific energy input)

$f_{0,l}^m$: Emission of gas m from operations other than energy combustion of a unit of device l (same as gas m's emission coefficient of device l)

$f_{k,l}^m$: Emission of gas wm from combustion of energy kind k by a unit energy use of device l

$\xi_{l,i}$: Energy saving ratio due to efficiency improvement in use of energy kind k by device l in sector i

$U_{k,l}$: Proportion of energy kind k used in device l for combustion operations, or burning rate (Note: 1- $U_{k,l}$ or proportion of k used for non-combustion operations in device l is taken as input in database system)

$d_{l,p,i}^m$: Emission rate (1- removal ratio) of gas m from combination of device l with removal process p in sector i

C.2.2 Emission constraints

Emission of gas m in sector i must not exceed allowable maximum emission limit in sector set Rz .

$$\sum_{i \in R_z} Q_i^m \le \hat{Q}_z^m \tag{C.3}$$

Where,

$\hat{Q}_z^m$: Allowable maximum limit on emission of gas *m* in group *z*

C.2.3 Service demand constraints

For a given service, its demand must be met by the quantity of service output supplied by all devices.

$$D_{j,i} \le \left(1 + \Psi_{j,i}\right) \cdot \sum_{(l,p) \in W_j} A_{l,j,i} \cdot X_{l,p,i} \tag{C.4}$$

Where,

$A_{l,j,i}$: Supply output of service *j* per operating unit of device *l* in sector *i* (same as specific service output)

$\Psi_{j,i}$: A measure of service efficiency of service type *j* in sector *i* (Note: Negative of $\Psi_{j,i}$, a measure of loss of service *j*, is taken as input in database system; Negative of $\Psi_{j,i}$ is the loss incurred during delivery of service *j*, for example transmission and distribution loss of electricity supply)

$D_{j,i}$: Service demand quantity of service type *j* in sector *i*

C.2.4 Device share ratio constraints

For a given service, ratio of service output of a device to total service output of all devices must not exceed its upper limit or maximum share.

$$\theta_{l,j,i} \cdot \sum_{(l',p') \in W_j} A_{l',j,i} \cdot X_{l',p',i} \ge A_{l,j,i} \cdot \sum_{p} X_{l,p,i} \tag{C.5}$$

Where,

$\theta_{l,j}$: Maximum share of device *l* in service *j*

C.2.5 Operating capacity constraints

Operating quantity of a combination of device l with removal process p must not exceed its stock net of operating rate.

$$X_{l,p,i} \le (1 + \Lambda_{l,i}) \cdot S_{l,p,i} \tag{C.6}$$

Where,

$1+\Lambda_{l,i}$: Operating rate of device *l* in sector *i* (Note: $1+\Lambda_{l,i}$ is taken as input in database system)

$S_{l,p,i}$: Stock of combination of device *l* with removal process *p* in sector *i*

C.2.6 Stock exchange constraints

Every device has a life. Stock of a device recruited in a given year will retire at the end of its life, with its quantity reducing linearly during its lifetime. Thus, out of total stock of a combination of device l with removal process p that was available in the previous year, a certain fraction (inverse of life of device) retires and the balance stock is passed on to the current year. Certain stock of previous year's combination of device l with removal process p can be replaced (or exchanged) in the current year by its combination with another removal process p1. However, the stock that is replaced in the current year cannot exceed the stock that is passed on from the previous year.

$$\overline{S}_{l,p,i} \cdot \left(1 - \frac{1}{\overline{T}_{l,i}}\right) \geq \sum_{p_1} M_{l,p \to p_1,i} \tag{C.7}$$

Where,

$\overline{S}_{l,p,i}$: Stock of combination of device l with removal process p in sector i in the previous year

$M_{l,p \to p_1,i}$:Previous year's stock of combination of device l with removal process p that is replaced in the current year by its combination with removal process $p1$

$\overline{T}_{l,i}$: Life of device l in sector i (this is the average life of stock of device l in previous year)

C.2.7 Energy supply constraints

Total quantity of supply of energy kind k cannot exceed its allowable maximum supply quantity in a sector.

$$\sum_{i \in G_i} \sum_{j} \left(\sum_{(l,p) \in W_j} \left(1 - \xi_{k,l,i}\right) \cdot E_{k,l,p,i} \cdot X_{l,p,i} \right) \leq \hat{E}_{k,G_i} \tag{C.8}$$

Where,

$\hat{E}_{k,G_i}$: Allowable maximum supply quantity of energy kind k

C.2.8 Internal Service and Internal Energy Balance

All internal energy kinds must be supplied as internal services from within the model (from energy conversion and supply sectors).

$$\sum_{i \in R_e} \left\{ \sum_{j \in V_{j,k}} \left(\left(1 + \Psi_{j,i}\right) \sum_{(l,p) \in W_j} A_{l,j,i} \cdot X_{l,p,i} \right) \right\} = \sum_{i \in R_e} \left\{ \sum_{k \in V_{j,k}} \left(\sum_{(l,p) \in W_j} \left(1 - \xi_{k,l,i}\right) \cdot E_{k,l,p,i} \cdot X_{l,p,i} \right) \right\} \tag{C.9}$$

C.2.9 Stock Balance

Stock of combination of device l and removal process p in the current year is equal to the sum of the stock of that combination transferred from previous year, the quantity of that combination recruited in current year, and the net stock of other combinations of device l that are exchanged by its combination with removal process p in current year.

$$S_{l,p,i} = \overline{S}_{l,p,i} \left(1 - \frac{1}{\overline{T}_{l,i}}\right) + r_{l,p,i} + \sum_{p_1} \left(M_{l,p_1 \to p,i} - M_{l,p \to p_1,i}\right) \tag{C.10}$$

Where,

$r_{l,p,i}$: Quantity of combination of device l with the removal equipment p recruited in current year in sector i

The performance of a device can also change over time. Average performance of combination of device l with removal process p on a given parameter in current year is estimated from the weighted average of performances of its stock passed on from previous year, its quantity recruited in current year, and the net stock of this combination that is obtained from exchanges with other combinations of device l in current year. Expressions (C.11), (C.12), (C.13), and (C.14) estimate the average performance of combination of device l with removal process p on different performance-parameters. Note: expression (C.14) is not used in current version on the model.

$$d^m_{l,p,i} \cdot S_{l,p,i} = \overline{d}^m_{l,p,i} \cdot \left\{ \overline{S}_{l,p,i} \left(1 - \frac{1}{\overline{T}_{l,i}}\right) - \sum_{p_1} M_{l,p\to p_1,i} \right\} + \overset{\circ}{d}{}^m_{l,p,i} \cdot \left(r_{l,p,i} + \sum_{p_1} M_{l,p_1\to p,i} \right) \tag{C.11}$$

$$E_{k,l,p,i} \cdot S_{l,p,i} = \overline{E}_{k,l,p,i} \cdot \left\{ \overline{S}_{l,p,i} \left(1 - \frac{1}{\overline{T}_{l,i}}\right) - \sum_{p_1} M_{l,p\to p_1,i} \right\}$$
$$+ \overset{\circ}{E}_{k,l,p,i} \cdot r_{l,p,i} + \sum_{p_1} \left(\overline{E}_{k,l,p_1,i} + \Delta^E_{k,l,p_1\to p} \right) \cdot M_{l,p_1\to p,i} \tag{C.12}$$

$$A_{l,j,i} \cdot \sum_p S_{l,p,i} = \overline{A}_{l,j,i} \cdot \left\{ \sum_p \overline{S}_{l,p,i} \left(1 - \frac{1}{\overline{T}_{l,i}}\right) - \sum_{p_1} M_{l,p\to p_1,i} \right\}$$
$$+ \overset{\circ}{A}_{l,j,i} \cdot \sum_p r_{l,p,i} + \overline{A}_{l,j,i} \cdot \sum_{p_1} M_{l,p_1\to p,i} \tag{C.13}$$

$$T_{l,i} \cdot \sum_p S_{l,p,i} = \overline{T}_{l,i} \cdot \sum_p \overline{S}_{l,p,i} \left(1 - \frac{1}{\overline{T}_{l,i}}\right) + \overset{\circ}{T}_{l,i} \cdot \sum_p r_{l,p,i} \tag{C.14}$$

Where,

$\overline{d}^m_{l,p,i}$: Emission rate (1- removal ratio) of gas m from combination of device l with removal process p in sector i in the previous year

$\overset{\circ}{d}{}^m_{l,p,i}$: Emission rate (1- removal ratio) of gas m from combination of device l with removal process p in sector i, for stock of that combination obtained in the current year from either recruitment or exchange with other combinations.

$\overline{E}_{k,l,p,i}$: Energy use of energy kind k per operating unit (or specific energy input) of combination of device l with removal process p in sector i in the previous year

$\overset{\circ}{E}_{k,l,p,i}$: Energy use of energy kind k per operating unit (or specific energy input) of combination of device l with removal process p in sector i in the previous year, for stock of that combination recruited in current year.

$\Delta^E_{k,l,p_1\to p}$:Energy efficiency change due to exchange of combination of device l with removal process $p1$ to its combination with removal process p

$\overline{A}_{l,j,i}$: Supply output of service j per operating unit (or specific service output) of device l in sector i in the previous year

$\overset{\circ}{A}_{l,j,i}$: Supply output of service *j* per operating unit (or specific service output) of device *l* in sector *i*, for stock of that combination recruited in the current year.

$T_{l,i}$: Average life of stock of device *l* in sector *i* in the current year

$\overset{\circ}{T}_{l,i}$: Life span of the recruited equipment *l* in sector *i*, for stock of that device recruited in the current year (Note: This parameter is assumed constant since equation (C.14) is not used in current version of the model).

Change in average performance of combination of device *l* with removal process *p* over time can be calculated by repeatedly calculating expressions (C.11), (C.12), (C.13), and (C.14) in every year.

C.2.10 Annualized initial investment cost (or annualized fixed cost or annualized capital cost)

Annualized initial investment cost as shown in expression (C.15) is used for evaluating recruitment of devices in a given year.

$$\sum_i \sum_j \sum_{(l,p)\in W_j} \left(\overset{\circ}{C}_{l,p} \cdot r_{l,p,i} + \sum_{p_1} \overset{\circ}{C}{}^{x}{}_{l,p_1 \to p} \cdot M_{l,p_1 \to p,i} \right) \tag{C.15}$$

$$\overset{\circ}{C}_{l,p} = \overset{\circ}{B}_{l,p} \cdot (1 - SC_{l,p}) \cdot \frac{\alpha(1+\alpha)^{\overset{\circ}{T}_{l,i}}}{(1+\alpha)^{\overset{\circ}{T}_{l,i}} - 1} \tag{C.16}$$

Where,

$\overset{\circ}{C}_{l,p}$: Annualized investment cost of a unit of combination of device *l* with removal process *p*

$\overset{\circ}{C}{}^{x}{}_{l,p_1 \to p}$:Annualized investment cost of exchanging a unit of combination (l, p_1) to (l, p)

$\overset{\circ}{B}_{l,p}$: Initial investment cost or fixed cost of recruiting one unit of combination of device *l* with removal process *p*

α : Discount rate

$SC_{l,p}$: Subsidy rate

$\overset{\circ}{B}_{l,p}$ is estimated by expressions (C.17) and (C.18).

$$\overset{\circ}{B}_{l,p} = \overset{\circ}{B}{}'_{l} + \overset{\circ}{b}{}''_{p} \cdot \sum_i \sum_k E_{k,l,p,i} \tag{C.17}$$

$$E_{k,l,p,i} = (1 + e_p) \cdot E'_{k,l,i} \tag{C.18}$$

Where,

$\overset{\circ}{B}{}'_{l}$: Initial investment cost or fixed cost of recruiting one unit of energy device *l*.

$\overset{\circ}{b}{}''_{p}$: Initial investment cost or fixed cost of removal process *p* per energy use of combination of device l with removal process p.

$E'_{k,l,i}$: Energy use of energy kind k per operating unit of energy device l.

e_p : Additional energy use rate of removal process p.

C.2.11 Running cost

Running cost in a given year comprises cost of energy used by devices, and cost of operation and maintenance of devices.

$$\sum_{(l,p)\in W_j}\left(g^0_{l,p,i}+\sum_k \xi_{l,i}\cdot\left(1-\xi_{k,l,i}\right)\cdot E_{k,l,p,i}\right)\cdot X_{l,p,i} \tag{C.19}$$

Where,

$g^0_{l,p,i}$: Operating cost per unit of combination of device l with removal process p in sector i

$g_{k,i}$: Price of energy kind k in sector i

$g^0_{l,p,i}$ is estimated by expressions (C.18) and (C.20)

$$g^0_{l,p,i}=g^{0'}_{l,i}+g^{0''}_p\cdot\sum_k E_{k,l,p,i} \tag{C.20}$$

Where,

$g^{0'}_{l,i}$: Operating cost per unit of energy device l in sector i

$g^{0''}_p$: Operating cost per unit of removal process p per energy use of combination of device l with removal process p

C.2.13 Objective Function

Objective function is the total cost in a given year as shown in expression (C.21). This comprises total annualized fixed cost (only for recruitments in that year), total running cost, and total cost of emission tax in that year. Decisions for recruitment quantity and operational quantity for all feasible combinations of devices and removal processes in a given year are made based on the criterion of total cost.

$$\begin{aligned}TC=\sum_i\Bigg(\sum_{(l,p)\in W_j}\Bigg\{&\mathring{C}_{l,p}\cdot r_{l,p,i}+\sum_{p_1}\mathring{C}^x{}_{l,p_1\to p}\cdot M_{l,p_1\to p,i}\\&+\left(g^0_{l,p,i}+\sum_k\left(g_{k,i}+\varepsilon_{k,i}\right)\cdot\left(1-\xi_{k,l,i}\right)\cdot E_{k,l,p,i}\right)\cdot X_{l,p,i}\Bigg\}+\sum_m\zeta^m_i\cdot Q^m_i\Bigg)\to\min\end{aligned} \tag{C.21}$$

$\xi_{l,i}$

Where,

TC : Total cost

$\varepsilon_{k,i}$: Tax on energy k in sector i

ζ^m_i : Emission tax on gas m in sector i

Appendix D. Terms of reference

Combination of device and removal process: It is defined as the combination of a device and a combination of removal process.

Combination of removal process: Combination of different removal processes at the stages of pre-combustion, in-site combustion and post-combustion, can be defined in AIM/Enduse. For each such combination, data for Removal rates for SO_2 and NO_x, Fixed cost, Operational cost, Energy consumption and Retrofit factor are specified by the user. A combination of removal process can be attached to a main device.

Countermeasure: A countermeasure is a type of intervention aimed at mitigating emission. Four types of countermeasures are defined in AIM/Enduse – Countermeasure at use stage, Tax, Regulation, and Subsidy.

Device or Energy device: A 'device' refers to a set of procedures/operations and/or machines/equipments. Unlike a technology that supplies final service, a service output from a device can be either final or intermediate. It must be noted that in AIM/Enduse a device is defined as an indivisible part of a technology, whereas in reality a device may itself comprise multiple parts (e.g. multiple machines). Thus the term 'device' is an imaginary concept used only for convenience of definition in AIM/Enduse. In AIM/Enduse, a device is represented by its unit, life, capital cost, operational cost, operating rate, specific inputs and outputs and their quantities used/produced by a unit of device. Examples of device include sintering machine (a single equipment to produce an intermediate service as part of a steel making technology), alumina production process (a set of equipments and operations to produce an intermediate service as a part of an aluminium production technology), incandescent lamp (a single equipment that entirely constitutes a technology to deliver a final service), wet process for making cement (a set of equipments and operations that entirely constitutes a technology to produce a final service).

Discount rate: 'Discount rate' is a way to measure how much we value future benefits today. For the purpose of evaluating competing technologies with different lives, in a particular year, AIM/Enduse model uses discount rate to convert investments required in capital, operational and energy costs in multiple years to the same base year. It can be defined as an average estimate of the real market interest rate or the discount rate on goods that the user team expects to prevail in a country over the time horizon of the model (typically next few decades). This definition is a reasonable representative of the cost of capital to the economy, and the returns to direct investments.

Efficiency of device: Efficiency of a device can be defined in multiple ways. Although 'efficiency' is not defined as a parameter in AIM/Enduse, it is captured in the combined definitions of specific service output and specific energy input. Efficiency can be defined as the quantity of service output produced or delivered by one unit of energy input. This definition is useful for data preparation since for most devices, figures for specific service output and specific energy input cannot be obtained directly but will need to be estimated from efficiency figures. Unit: Unit of service output per unit of energy input.

Emission coefficient of device: AIM/Enduse permits defining emission coefficients for a device for SO_2 and NO_x emissions that arise due to the process of operation of device. Unit: Grams (or Kilo-grams or Tons) of gas per unit of device.

Emission coefficient of energy: For each of the emissions – CO_2, SO_2 and NO_x – emission coefficient of energy is the quantity of emissions per unit of energy (fuel or material) used. Unit: Grams (or Kilograms or Tons) of gas emitted per unit of energy burnt (in case of fuels); or Grams (or Kilo-grams or Tons) of gas emitted per unit of material used (in case of materials like limestone).

End year of calculation: It is the last year of calculation in the model.

Energy or Energy kind or Energy type: In AIM/Enduse, 'energy' is an extended concept that refers to an input to a device. Such an input can be a primary fuel, a secondary fuel, electricity, heat, or a material. Examples include wood, coal, natural gas, crude oil (primary fuels); gasoline, kerosene, diesel (secondary fuels); and iron ore, crude steel, clinker (materials). An energy can be represented as either internal energy or external energy in AIM/Enduse. Possible units: Joules (or KJ, MJ, or GJ) or Kgoe (or Toe, Ktoe, or Mtoe) or Kgce (or Tce, Ktce, or Mtce) for energy inputs (fuels, electricity, heat); Units of mass, volume, area, length, or physical numbers for material inputs.

Exchange of combinations of removal process: In AIM/Enduse, a particular combination of removal process attached to a device in a given year can be replaced by another combination of removal process in the next year. If a device is not attached to any combination of removal process in a given year, then it is said to be attached to 'Non' (dummy combination signifying no removal process) in that year. Thus, in order for a combination of removal process to be introduced with a particular device in a given year, it has to either replace an already attached combination of removal process to that device, or replace 'Non'.

External service and External energy: An external service is a service that is produced in the model but not used as input in any device. Thus, an external service is a final service whose demand is provided by the user external to the model. Similarly, an external energy is an energy that is not produced from any device but is supplied from outside the model.

Fixed cost or Capital cost of device: It is the initial investment cost required to recruit one unit of a device. Unit: US$ (or 1000 US$) or domestic currency per unit of device in 1995 price (or 2000 price).

Fixed cost of removal process: It is the installation cost of a removal process per unit of energy input (to the main device). Unit: US$ (or 1000 US$) or domestic currency per energy unit.

GAMS: General Algebraic Modeling System (GAMS) is a software designed by GAMS Development Corporation (www.gams.com) for modeling linear, non-linear and mixed-integer optimization problems. Linear optimization formulation of AIM/Enduse model is written and solved in GAMS.

IDRISI32: IDRISI32 is a Geographical Information System (GIS) and image processing software designed by Clark Labs, Clark University (www.clarklabs.org) for supporting special analysis and environmental decision making.

Improvement of device: It is defined as the improvement in a device's performance over time on any of the following parameters – Fixed cost, Operational cost, Specific service output, Specific energy input, Emission coefficient.

Internal service and Internal energy: An intermediate service, i.e. a service output from a device that goes as an energy input to another device, is classified as both internal service and internal energy in the model. The quantities of flow of such internal service and internal energy have to be balanced inside the model. Examples include electricity (output from power plants, input to enduse devices like refrigerator in households or smelting process in aluminium plant), alumina (output from Bayer's process, input to smelting process, both in aluminium plant), and gasoline (output from refineries, input to enduse devices like two-wheelers and cars).

Life of device: 'Life' of a device is the number of years over which the device remains operationally useful. Unit: Number of years.

Material: 'Material' is not used as a term in AIM/Enduse model. In this manual we sometimes use 'material' to refer to non-energy inputs or outputs. In AIM/Enduse, all material inputs are identified as 'energy' and all material outputs are identified as 'services'.

Maximum share of device: It is the upper bound on share of a device.

Operating rate of device: It is defined as the operating capacity of a device divided by its rated capacity. Normally it is less than 100% because of loss of capacity due to scheduled and unscheduled maintenance or outage of a device. Therefore, total operating capacity of a device available in a given year is estimated by multiplying its stock with operating rate.

Operation of device: It is defined as the process of running a device to produce a service.

Operational cost of device: It is the annual cost incurred in operating one unit of a device. This includes fixed operational and maintenance cost including wages, variable operational and maintenance cost, overhead cost, logistics costs, and other costs that are not included in 'Fixed cost' and 'Price of energy'. Unit: US$ (or 1000 US$) or domestic currency per unit of device per year, in 1995 price (or 2000 price).

Operational cost of removal process: It is the running cost of a removal process per year. Unit: US$ (or 1000 US$) or domestic currency.

Price of energy: It is the price of purchase (or market price) of one unit of a fuel. Preferable unit: US$ (or 1000 US$) or domestic currency per unit of energy, in 1995 price (or 2000 price).

Recruitment of device: It is defined as the process of purchase and installation of a device.

Reference year: It is the year for which the input data in the model is calibrated with actual figures. Normally, it is same as the start year of calculation in the model.

Region: It refers to a geographical area defined for the purpose of carrying out emission mitigation analysis. In AIM/Enduse, regions are classified by country (region classification 1).

Region classification 1: It refers to aggregate regional classification defined by the user in AIM/Enduse database system. A country level classification is an example of Region classification 1. Region classification 2, a disaggregate regional classification (for example, district level), is not used in the current version of AIM/Enduse. Although Region classification 2 is not used in this manual, it will be introduced in future versions of the model.

Regulation: A regulation is a constraint or upper limit imposed on quantity of use of energy or quantity of emission.

Removal process: In AIM/Enduse, an equipment or set of equipments and/or procedures, attached to a main device, for sole purpose of reducing SO_2 or NO_x from the main device, is called a 'removal process'. Three kinds of removal processes – introduced at pre-combustion, in-situ combustion, and post-combustion stages – can be defined in AIM/Enduse. For example, coal washing equipment attached before the boiler (pre-combustion stage) in a coal-fired power plant is a removal process that reduces sulphur content of coal, and hence, SO_2 emissions. Limestone addition during combustion of coal is an example of in-situ stage removal process, while Flue gas desulfurization is an example of post-combustion removal process.

Removal rate of removal process: Removal rate of a removal process is defined as the percentage of SO_2 or NO_x emission that it reduces from any device to which it is attached.

Retrofit factor of combination of device and removal process: Retrofit factor is defined as the proportion of a device's stock that is combined with a combination of removal process.

Sector: A 'sector' refers to a portion of an economy. For convenience, an economy is classified into a finite number of sectors. In bottom-up energy models like AIM/Enduse, this classification is based on the energy dynamics. Therefore, each sector is unique with respect to following characteristics: sources of service demands, patterns of energy flows, and technologies or devices used to satisfy service demands. Refer to Appendix D for examples of classification of sectors.

Service or Service kind or Service type: A 'service' refers to a measurable need within a sector that has to be satisfied. A service can be satisfied by supplying an output from a device. Thus, in AIM/Enduse, a service is identified by such an output. A service output from a device can be either a final output (external service) that satisfies a need of an enduse consumer, or an intermediate output (internal service) that goes as an input to another device. A service can be defined in either tangible or abstract terms. Examples include finished steel products (tangible, final output of steel making technologies), person-km traveled by road (abstract, final output of road transport vehicles), crude steel (tangible, intermediate output from blast furnace and converter), and heat energy for raising superheated steam (abstract, intermediate output from heat exchanger in combined cycle power plant). It must be noted here that concepts of 'final service' and 'intermediate service' are defined by the user team for convenience of energy system modeling, and may not necessarily imply real-life interpretations of these terms. For example, finished steel products like bars and beams may be defined as final service in AIM/Enduse model, whereas in reality they are intermediate services in an economy. Refer to Appendix D for examples of classification of services.

Service demand: It refers to the quantified demand created by a service. Service outputs from devices satisfy service demands. Possible units: Refer to Appendix D for a list of possible units of service demands.

Service efficiency: This concept is defined as opposite to service loss. It is used in this manual to signify the efficiency of supply or delivery of a service. Please refer to 'Service loss' for further description.

Service loss: It is a term used for representing transmission & distribution loss (in percentage) of electricity or loss during supply of any other service in AIM/Enduse.

Share of device: It is the share of a device's contribution in meeting a service demand. In case a device can produce multiple service outputs, its share can be defined separately for each service.

Specific energy input or Specific energy consumption of device: It is the quantity of energy input used by one unit of device in one year. It can be defined in AIM/Enduse as either the maximum potential energy input, or the net energy input, used by one unit of device in a year. It is separately defined for each fuel or material that a device uses. Unit: Unit of energy per unit of device.

Specific service output of device: It is the quantity of service output produced or delivered by one unit of device in one year. It can be defined in AIM/Enduse as either the maximum potential service output, or the net utilized service output, produced by one unit of device in a year. It is separately defined for each service that a device produces. Unit: Unit of service output per unit of device.

Start year of calculation: It is the starting year of calculation in the model.

Stock of device: It is the quantity of a device (expressed in units of device) available in a given year. It is equivalent to the rated capacity of a device available in a country in a given year. In AIM/Enduse, stock of each device needs to be specified at the beginning of reference year. Stock of a device in future years is calculated by the model. Unit: Same as unit of device.

Subsidy rate: A subsidy is concession (in percentage) on cost offered to promote a technology. In AIM/Enduse, subsidy can be applied to fixed cost or operational cost of a device or a combination of removal process.

Tax rate: A tax rate can be applied to an energy or an emission. Unit: US$ (or 1000 US$) or domestic currency per unit of energy or emission.

Technology or Technology system: A 'technology' or 'technology system' refers to a set of devices, coupled with a combination of removal processes, which can be employed to convert material and energy inputs to produce a service output for meeting a final service demand. A device implies a set of procedures and/or machines. A technology can be represented by material and energy flows through a sequence of devices, where each device may or may not be attached to a combination of removal processes (see Figure 2.2 in Chapter 2). Examples of technology with multiple devices include steel making by basic oxygen process, and aluminium production by bayer's process. In certain cases a technology may refer to a single device. For example, electric pump for pumping water for irrigation, and incandescent lamp for lighting.

Unit of device: 'Unit' of a device is defined to measure its stock or quantity in a given year. Possible units: Physical unit of device (e.g. number of devices); Unit of rated operational capacity of device (e.g. MW for power plant); or Unit of service output of device (i.e. same as the unit of service demand). Examples include: Number of incandescent lamps; Mega-Watts of coal-fired power plant; Tons of capacity (equivalent to tons of crude steel production) of electric arc furnace used for steel making.

Useful energy service: It refers to the service output of a device expressed in equivalent energy units. Although this term is not used in AIM/Enduse model, it is used in this document to distinguish energy services like heat or electricity from non-energy services like steel or road passenger transport.

Utility: It is a general term for fuels for boiler, industrial-owned power generation and industrial furnace.

Appendix E: Possible classifications for sectors and services

Sector		Service		Possible measures/units of service demand	
Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Agriculture	Agriculture	Irrigation	Irrigation	Irrigated area; No. of pumps; Useful energy service for pumping	Irrigated area; No. of pumps; Useful energy service for pumping
		Other energy uses	Farm land preparation	Agriculture value added; Useful energy service for non-pumping agriculture activities	No. of tractors; Useful energy service for land preparation
			Harvesting		Area of crop harvested; Useful energy service for harvesting
Transport	Transport – road	Road passenger	Private passenger transport	Person-km; Vehicle-km; No.of vehicles	Person-km; No. of private vehicles
			Public passenger transport		Person-km; No. of public vehicles
		Road freight	Road freight	Ton-km; No.of freight vehicles	Ton-km; No. of freight vehicles
	Transport – rail	Rail passenger	Rail passenger	Person-km; No. of operational locomotives	Person-km; No. of operational locomotives
		Rail freight	Rail freight	Ton-km: No. of operational locomotives	Ton-km: No. of operational locomotives
	Transport – air	Air passenger	Air passenger – domestic travel	Person-km; Km of passenger flights	Person-km; Km of passenger flights
			Air passenger – international travel		Person-km; Km of passenger flights
		Air freight	Air freight – domestic travel	Ton-km; Km of cargo flights	Ton-km; Km of cargo flights
			Air freight – international travel		Ton-km; Km of cargo flights
	Transport – water	Water passenger	Water passenger	Person-km; Km of passenger movement by ships	Person-km; Km of passenger movement by ships
		Water freight	Water freight	Ton-km; Km of goods movement by ships	Ton-km; Km of goods movement by ships
Residential	Residential - rural	Cooking	Rural – cooking	Useful energy service for cooking; No. of households; Population	Useful energy service for rural cooking; No. of rural households; Rural population
		Lighting	Rural – lighting	Lumen-hr; No. of lamps, No. of households	Lumen-hr; No. of lamps in rural areas, No. of rural households
		Space cooling	Rural – fan	Useful energy service for cooling, No. of households	No. of fans; Fan hrs use in rural areas, No. of rural households
		Space heating	Rural – refrigerator	Useful energy service for heating, No. of households	No. of refrigerators in rural areas, No. of rural households
		Refrigerator	Rural – air conditioner	No. of refrigerators, No. of households	No. of ACs; AC hrs use in rural areas, No. of rural households
		Monochrome TV	Rural – monochrome TV	No. of TVs; TV-hrs use, No. of households	No. of TVs; TV-hrs use in rural areas

Sector		Service		Possible measures/units of service demand	
Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Residential		Color TV	Rural – color TV	No. of TVs; TV-hrs use, No. of households	No. of TVs; TV-hrs use in rural areas, No. of rural households
		Washing machine	Rural – washing machine	No. of washing machines; Washing machine-hrs use, No. of households	No. of washing machines; Washing machine-hrs use in rural areas, No. of rural households
		Other appliances	Rural – other appliances	Population; Energy use* in appliances, No. of households	Rural population; Energy use* in other appliances in rural areas, No. of rural households
	Residential - urban		Urban – cooking		Useful energy service for urban cooking; No. of urban households
			Urban – lighting		Lumen-hr; No. of lamps in urban areas, No. of urban households
			Urban – fan		No. of fans; Fan hrs use in urban areas, No. of urban households
			Urban – refrigerator		No. of refrigerators in urban areas, No. of urban households
			Urban – air conditioner		No. of ACs; AC hrs use in urban areas, No. of urban households
			Urban – monochrome TV		No. of TVs; TV-hrs use in urban areas, No. of urban households
			Urban – color TV		No. of TVs; TV-hrs use in urban areas, No. of urban households
			Urban – washing machine		No. of washing machines; Washing machine-hrs use in urban areas, No. of urban households
			Urban – other appliances		Urban population; Energy use* in other appliances in urban areas, No. of urban households
Commercial	Restaurants and hotels	Lighting	Cooking – restaurants	Lumen-hr; No. of lamps, Total floor area in commercial establishments	Useful energy service for cooking in restaurants; No. of restaurants
		Air conditioner	Lighting – restaurants	No. of Acs, Total floor area in commercial establishments	Lumen-hr; No. of lamps in restaurants, No. of restaurants
		Refrigerator	Air conditioner – restaurants	No. of refrigerators, Total floor area in commercial establishments	No. of ACs in restaurants, No. of restaurants
		Computer	Other appliances – restaurants	No. of computers, Total floor area in commercial establishments	No. of restaurants; Value added in restaurants; Energy use* in other appliances in restaurants

Sector		Service		Possible measures/units of service demand	
Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Commercial	Corporate and Government offices	Other appliances	Lighting – offices	Commercial value added; Energy use* in other appliances in commercial sector, Total floor area in commercial establishments	Lumen-hr; No. of lamps in offices, Total floor area in offices
			Air conditioner – offices		No. of ACs in offices, Total floor area in offices
			Computer – offices		No. of computers in offices, Total floor area in offices
			Other appliances – offices		Value added in offices; Energy use* in other appliances in offices, Total floor area in offices
	Hospitals and clinics		Lighting – hospitals		Lumen-hr; No. of lamps in hospitals, Total floor area in hospitals & clinics
			Air conditioner – hospitals		No. of ACs in hospitals, Total floor area in hospitals & clinics
			Other appliances – hospitals		Value added in hospitals; Energy use* in other appliances in hospitals, Total floor area in hospitals & clinics
	Other commercial establishme nts		Lighting – other commercial		Lumen-hr; No. of lamps in other commercial establishments, Total floor area in other establishments
			Air conditioner – other commercial		No. of ACs in other commercial establishments, Total floor area in other establishments
			Other appliances – other commercial		Value added in other commercial establishments; Energy use* in other appliances in other commercial establishments, Total floor area in other establishments
Industry	Industry – steel	Finished steel products	Hot rolled steel	Ton	Ton
			Cold rolled steel		Ton
			Crude steel**		Ton
			Sinter**		Ton
			Pig iron**		Ton
			Coke gas**		Cubic meters
			Coke**		Ton
			Heat**		Energy unit
			Electricity**		Energy unit
	Industry – aluminium	Finished aluminium products	Finished aluminium	Ton	Ton
			Molten aluminium**		Ton
			Alumina**		Ton
			Heat**		Energy unit
			Electricity**		Energy unit

Sector		Service		Possible measures/units of service demand	
Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Industry	Industry – cement	Cement	Cement	Ton	Ton
			Pre-grinded cement**		Ton
			Portland cement**		Ton
			Blast furnace cement**		Ton
			Fly ash cement**		Ton
			Clinker**		Ton
			Heat**		Energy unit
			Electricity**		Energy unit
	Industry – paper	Paper	Finished paper	Ton	Ton
			Dried paper**		Ton
			Bleached pulp**		Ton
			Mechanical pulp**		Ton
			Waste pulp**		Ton
			Semi chemical pulp**		Ton
			Kraft pulp**		Ton
			Heat**		Energy unit
			Electricity**		Energy unit
	Industry – petrochemicals	Petrochemical products	Ethylene	Ton	Ton
			Low density polyethylene		Ton
			High density polyethylene		Ton
			Polypropylene		Ton
			Polystylene		Ton
			Other petrochemical products		Ton
			Heat**		Energy unit
			Electricity**		Energy unit
	Industry – brick	Bricks	Bricks	No. of bricks	No. of bricks
			Heat**		Energy unit
	Industry – caustic soda	Caustic soda	Caustic soda	Ton	Ton
			Brine**		Ton
			Heat**		Energy unit
	Industry – soda ash	Soda ash	Soda ash	Ton	Ton
			Brine**		Ton
			Calcined sodium bicarbonate**		Ton
			Heat**		Energy unit
			Electricity**		Energy unit
	Industry – fertilizer	Fertilizer products	Phosphatic fertilizer products	Ton	Ton
			Nitrogenous fertilizer products		Ton
			Ammonia**		Cubic meters
			Synthesis gas**		Cubic meters
			Heat**		Energy unit
			Electricity**		Energy unit
	Industry – textiles	Textile products	Finished cotton cloth	Square metre; Ton	Square metre; Ton
			Weaved cloth**		Square metre; Ton
			Spinned cloth**		Square metre; Ton
			Electricity**		Energy unit
			Non-cotton textile products		Ton

Sector		Service		Possible measures/units of service demand	
Alternative 1	Alternative 2	Alternative 1	Alternative 2	Alternative 1	Alternative 2
Industry	Industry – sugar	Finished sugar	Finished sugar	Ton	Ton
			Crystallized sugar**		Ton
			Concentrated juice**		Cubic meters
			Clear juice**		Cubic meters
			Heat**		Energy unit
			Electricity**		Energy unit
	Industry – mining	Value added in mining	Value added in mining	Value added in US$	Value added in US$
			Heat		Energy unit
			Electricity		Energy unit
	Industry – construction	Value added in construction	Value added in construction	Value added in US$	Value added in US$
			Heat		Energy unit
			Electricity		Energy unit
	Other industries	Value added in other industries	Value added in other industries	Value added in US$	Value added in US$
			Heat demand in other industries		Energy unit
			Electricity demand in other industries		Energy unit
Electricity generation & supply	Electricity generation & supply	Electricity	Electricity	Energy unit	Energy unit
	Combined heat and electricity generation (CHP)	Heat	Electricity	Energy unit	Energy unit
			Heat		Energy unit
Oil refining & supply	Crude oil production	Petroleum products	Crude oil	Energy unit	Energy unit
	Oil refining & supply		Gasoline		Energy unit
			Diesel		Energy unit
			Heavy oil		Energy unit
			Kerosene		Energy unit
			LPG		Energy unit
			Other petroleum products		Energy unit
Natural gas production & supply	Natural gas production & supply	Natural gas	Natural gas (uncompressed)	Energy unit	Energy unit
			CNG		Energy unit
			Hydrogen		Energy unit
Coal production & supply	Coal production & supply	Coal products	Anthracite	Energy unit	Energy unit
			High grade bituminous coal		Energy unit
			Sub-bituminous coal		Energy unit
			Lignite		Energy unit
Biomass production & supply	Traditional biomass production & supply	Traditional biomass	Fuelwood	Energy unit	Energy unit
			Cattle-dung		Energy unit
			Crop residue		Energy unit
	Modern biomass production & supply	Modern biomass (commercial energy plantation)	Modern biomass products	Energy unit	Energy unit

Note:
i) Sectors, services, and measures/units under alternative 1 should be read together. Similarly, those under alternative 2 should be read together.
ii) The classifications and units given in this table are mere examples. Exact classification and choice of measures and units should depend on the energy-economy context of a country, availability of data for services and technologies, and the user team's judgment.
iii) * In a bottom-up model like AIM/Enduse a service must be expressed in some measure of output of device, so that efficiency improvement options can be evaluated; Thus use of 'Energy use' as a measure of service must be avoided as far as possible.
iv) ** These items can be represented as internal services in AIM/Enduse. However, some of them can also be represented as external service or external energy if their supply is external to the model.

Appendix F: Calorific value, price, and emission coefficients of energy kinds

Table F.1. Calorific values and emission coefficients

Energy kind	Calorific value	Emission coefficients	
		CO_2 (t-C/TJ)	SO_2 (kg-SO_2/TJ)
Crude oil	1.0 to 1.023 toe/ton (7.3 to 7.5 barrels/ton)*	IPCC average: 20.0 Japan: 18.66	Japan: 35.1
Natural gas liquids	1.02 toe/ton (1.12 toe/ton for Thailand)	IPCC average: 17.2	
Ethane	1.13 toe/ton	IPCC average: 16.8	
LPG	1.13 toe/ton (1.088 toe/ton for Malaysia) (1.10 toe/ton for China)	IPCC average: 17.2 Japan: 16.32	Japan: 0.8 India: Negligible
Naphtha	1.075 toe/ton (1.054 toe/ton for Malaysia)	IPCC average: 20.0 Japan: 18.16 India: 15.4	Japan: 2.92 India: 111.1
Aviation gasoline	1.07 toe/ton (1.05 toe/ton for Malaysia)	IPCC average: 18.9 Japan: 18.29 India: 18.4	India: 23.2
Motor gasoline	1.07 toe/ton (1.05 toe/ton for Malaysia) (1.03 toe/ton for China)	IPCC average: 18.9 Japan: 18.29 India: 18.6	Japan: 3.8 India: 108.7
Jet gasoline	1. 07 toe/ton	IPCC average: 18.9	
Jet kerosene	1.065 toe/ton (1.032 toe/ton for Malaysia) (1.02 toe/ton for China)	IPCC average: 19.5 Japan: 18.31 India: 18.4	Japan: 52.55
Other kerosene	1.045 toe/ton (1.032 toe/ton for Malaysia) (1.02 toe/ton for China)	IPCC average: 19.6 Japan: 18.51 India: 18.4	Japan: 1.7 India: 116.2
Gas/diesel oil	1.035 toe/ton (1.015 toe/ton for Malaysia) (1.20 toe/ton for China)	IPCC average: 20.2 Japan: 18.72 India: 20.0	Japan: 59.6 India: 465.2
Heavy fuel oil	0.96 toe/ton (0.991 toe/ton for Malaysia) (1.03 toe/ton for China)	IPCC average: 21.1 Japan (type A): 18.90 Japan (type C): 19.54 India: 21.1	Japan (type A): 207.0 Japan (type C): 662.2 India: 1993.6
Lubricants	0.96 toe/ton (1.006 toe/ton for Malaysia)	IPCC average: 20.0	
Bitumen	0.96 toe/ton (0.998 toe/ton for Malaysia)	IPCC average: 22.0	
Paraffin waxes	0.96 toe/ton (1.035 toe/ton for Malaysia)		
Petroleum coke	0.74 toe/ton 0.869 toe/ton for Malaysia)	IPCC average: 27.5	
Other petroleum products	0.96 toe/ton (1.015 toe/ton for Malaysia)	IPCC average: 20.0 Japan: 20.77 India: 18.6	

Table F.1. Calorific values and emission coefficients (continued)

Fuel	Calorific value	Emission coefficients	
		CO_2 (t-C/TJ)	SO_2 (kg-SO_2/TJ)
Hard coal	0.47 to 0.63 toe/ton* (0.50 to 0.63 toe/ton for China)	IPCC average: 25.8 Japan: 24.71 India: 25.6	Japan: 333.0 India: 549.1
Lignite/Brown coal/Sub-bituminous coal	0.20 to 0.42 toe/ton (0.20 to 0.29 toe/ton for most Asian countries)*	IPCC average: 26.2 to 27.6 India: 25.6	India: 549.1
Coking coal	0.44 to 0.70 toe/ton * (0.55 to 0.85 toe/ton for China)	IPCC average: 25.8 Japan: 23.65 India: 29.4	Japan: 300.6 India: 549.1
Other bituminous coal and anthracite	0.44 to 0.70 toe/ton *	IPCC average: 25.8 to 26.8 India: 25.6	India: 549.1
Peat	0.20 toe/ton	IPCC average: 28.9	
Coke oven coke and lignite coke	0.63 to 0.65 toe/ton * (0.99 toe/ton for China)	IPCC average: 29.5 Japan: 29.4 India: 29.4	Japan: 411.7
Peat briquettes	0.43 to 0.48 toe/ton *	IPCC average: 28.9	
Coke oven gas	0.64 toe/ton	IPCC average: 13.0	Japan: 7.5
Blast furnace gas		IPCC average: 66.0	Japan: 30.5
Charcoal	0.736 toe/ton		
Natural gas	0.901 toe/1000m^3 (0.40 to 0.43 toe/1000m^3 for China) (0.97 toe/1000m^3 for Indonesia)	IPCC average: 15.3 Japan: 13.47 Japan (town gas): 13.14 India: 14.2	Japan: 1.47 India: Negligible
Solid biomass	Fuelwood: 0.36 toe/ton (0.40 toe/ton for China) Dung: 0.29 toe/ton (0.30 to 0.37 toe/ton for China) Agricultural waste: 0.36 toe/ton (0.30 to 0.37 toe/ton for China) Bagasse: 0.19 toe/ton	IPCC average: 29.9	Japan (fuelwood): 63.2 India (fuelwood): 53.3 India (dung): 42.9 India (agricultural waste): 46.2
Liquid biomass	0.65 toe/ton	IPCC average: 20.0	
Gas biomass	Biogas: 0.50 toe/ton for China	IPCC average: 30.6	

Note: Japan's emission factors are based on low heating values; Other numbers are based on high heating values.
* These numbers are country-specific. Refer to IEA (2001) for further details.
Sources: IEA (2001); IPCC (2001), IPCC (1996b); Garg and Shukla (2002); JEA (1992, 1998); EDMC (2002)

Table F.2. Crude oil spot prices in 2001 (in US$/barrel)

Source	Price
Brent	24.46
West Texas Intermediate	25.89
West Texas Sour	23.17
Lousiana Light Sweet	25.95
Arab Light	26.75*
Fatah-Dubai	22.81
Iranian Light	22.61
Iranian Heavy	22.08
Urals	23.12
Minas	24.06
Tapis	25.33

* Valid for 2000
Source: IEA (2002)

Table F.3. Oil product spot prices in 2001 (in US$/barrel)

Product	Market		
	USA	Singapore	NW Europe (Rotterdam)
Gasoline	30.96	27.50	28.91
Gas oil	29.78	27.29	29.15
Jet kerosene	31.12	28.31	30.82
Naphtha	-	23.78	23.73
Low sulfur fuel oil	20.68	21.83	19.54
High sulfur fuel oil	17.35	29.37	17.82

Source: IEA (2002)

Table F.4. Prices of enduse energy (in 1000 national currency/toe (NCV))

	Country:	Korea	China	India	Indonesia	Japan	Thailand
Exchange rate in 2000 (1US$ =):		‘000Won 1.131	‘000Yuan 0.00828	‘000Rs. 0.0449	‘000Rupiah 0.0084	‘000Yen 0.1078	‘000Bath 0.0401
Exchange rate in 1999 (1US$ =):		-	-	0.0431	0.0079	0.1139	0.0378
Exchange rate in 1998 (1US$ =):		-	-	-	0.0100	0.1309	-
Exchange rate in 1997 (1US$ =):		-	-	-	-	0.1209	-
Energy	Sector						
Steam coal	Industry	0.094	0.415	1.21**,+	169.1#	6.79	1.92*
	Households	-	0.451	-	-	-	-
	Electricity generation	-	-	-	-	13.33##	-
Light fuel oil	Industry	0.668	-	12.34**	305.0#	37.12	-
	Households	0.701	-	9.11	338.2**	60.12	18.97
	Electricity generation	-	-	-	-	-	-
High sulfur fuel oil	Industry	0.351	-	8.41**	362.9#	27.49	10.39
	Households	-	-	-	-	-	-
	Electricity generation	0.341	-	8.41**	-	26.27##	-
Low sulfur fuel oil	Industry	0.363	-	-	-	35.14	7.08**
	Households	-	-	-	-	-	-
	Electricity generation	-	-	-	-	-	-
Electricity	Industry	0.852	-	41.88*	2,425.1**	188.84**	26.51*
	Households	1.068	-	20.26*	2,253.5#	268.72*	27.91*
	Electricity generation	-	-	-	-	-	-
Natural gas	Industry			1.84*,+	883.0#	54.22*	4.84*
	Households			-	111.3#	155.00*	-
	Electricity generation			-	-	28.46##	-

* Valid for 2000; ** Valid for 1999; # Valid for 1998; ## Valid for 1997

+ Price excluding tax (all other prices are inclusive of taxes)

Sources: IEA (2002); IMF (2001)

Appendix G: Units and conversions

Following tables have been reproduced from IEA (2001).

Table G.1. Conversion factors for energy

To:	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388 x 10^{-5}	947.8	0.2778
Gcal	4.1868 x 10^{-3}	1	10^{-7}	3.968	1.163 x 10^{-3}
Mtoe	4.1868 x 10^{4}	10^{7}	1	3.968 x 10^{7}	11630
MBtu	1.0551 x 10^{-3}	0.252	2.52 x 10^{-8}	1	2.931 x 10^{-4}
GWh	3.6	860	8.6 x 10^{-5}	3412	1

Table G.2. Conversion factors for mass

To:	Kilogram	Ton	Pound
From:	multiply by:		
Kilogram	1	0.001	2.2046
Ton	1000	1	2204.6
Pound	0.454	4.54 x 10^{-4}	1

Table G.3. Conversion factors for volume

To:	U.S.	U.K.	Barrel	Cubic	Litre	Cubic
From:	multiply by:					
U.S. gallon	1	0.8327	0.02381	0.1337	3.785	0.0038
U.K. gallon	1.201	1	0.02859	0.1605	4.546	0.0045
Barrel	42.0	34.97	1	5.615	159.0	0.159
Cubic foot	7.48	6.229	0.1781	1	28.3	0.0283
Litre	0.2642	0.220	0.0063	0.0353	1	0.001
Cubic	264.2	220.0	6.289	35.3147	1000.0	1

Appendix H: Characteristics of technologies in AIM-India

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./yr.)
Agriculture sector									
Tractor	1 tractor	10	5000	Tilling	1000 no	0.001	Diesel	80	0.34
New tractor	1 tractor	10	5000	Tilling	1000 no	0.001	Diesel	60	0.25
Diesel pump for irrigation	1 pump	10	250	Irrigation	toe	0.5	Diesel	1600	6.70
New diesel pump for irrigation	1 pump	10	250	Irrigation	toe	0.5	Diesel	1350	5.65
Electric pump for irrigation	1 pump	10	375	Irrigation	toe	1	Electricity	3000	-
New electric pump (irrigation)	1 pump	10	375	Irrigation	toe	1	Electricity	2500	-
Diesel engine for threshing	1 thresher	10	500	Threshing	toe	0.001	Diesel	3.3	0.01
New diesel engine (threshing)	1 thresher	10	500	Threshing	toe	0.001	Diesel	2.8	0.01
Electric motor for threshing	1 thresher	10	500	Threshing	toe	0.002	Electricity	6.2	-
New electric motor (threshing)	1 thresher	10	500	Threshing	toe	0.002	Electricity	5	-
Aluminium industry									
Bayer's process	1 ton Al	30	1500	Alumina	ton	2.01	Coal	495	6.48
							Electricity	65	
							Fuel oil	157.7	
							Bauxite	5.4	
Improved bayer's process	1 ton Al	30	2000	Alumina	ton	2.01	Coal	360	5.03
							Electricity	55	
							Fuel oil	130	
							Bauxite	5.4	
Energy efficient ALCOA process	1 ton Al	30	2500	Alumina	ton	2.01	Coal	270	4.07
							Electricity	48	
							Fuel oil	120	
							Bauxite	5.4	
Al smelting process (Hall-Heroult)	1 ton Al	20	47000	Molten aluminium	ton	1.02	Alumina	2.01	0.77
							Electricity	1530	
							Fuel oil	107.5	
New Al smelting process (Hall-Heroult with pre-baked anodes)	1 ton Al	20	50000	Molten aluminium	ton	1.02	Alumina	2.01	0.77
							Electricity	1340	
							Fuel oil	80	
New Al smelting process – advanced	1 ton Al	20	51000	Molten aluminium	ton	1.02	Alumina	2.01	0.77
							Electricity	1150	
							Fuel oil	70	
Al casting & rolling (conventional)	1 ton Al	20	1500	Alminium	ton	1	Molten Al	1.02	0.59
							Electricity	125	
							Fuel oil	82	
Al casting & rolling (continuous)	1 ton Al	20	1750	Alminium	ton	1	Molten Al	1.02	0.59
							Electricity	65	
							Fuel oil	82	
New Al casting & rolling (continuous & improved)	1 ton Al	20	2500	Alminium	ton	1	Molten Al	1.02	0.59
							Electricity	50	
							Fuel oil	70	
Brick making industry									
Bull trench kiln – 1	1 million no.	15	4000	Brick	million no	1	Coal	117640	1478
Bull trench kiln – 2	1 million no.	15	3500	Brick	million no	1	Coal	94190	1183
Clamps	1 million no.	25	5000	Brick	million no	1	Biomass	134570	563
High draught kiln	1 million no.	15	6500	Brick	million no	1	Coal	71770	902
vertical shaft brick kiln	1 million no.	15	4000	Brick	million no	1	Coal	57420	721
Caustic soda industry									
Brine preparation & purification	1 ton caustic soda	30	40	Brine	ton	2.1	Salt	3.36	0.42
							Electricity	3.17	
							Heat	12.9	
Improved brine preparation & purification	1 ton caustic soda	30	50	Brine	ton	2.1	Salt	3.36	0.29
							Electricity	2.9	
							Heat	9	
Diaphragm cell electrolysis	1 ton caustic soda	30	100	Cell liquor	ton	1.4	Brine	2.1	-
							Electricity	290	
Mercury cell electrolysis	1 ton caustic soda	30	110	Caustic soda	ton	1	Brine	2.1	-
							Electricity	250	
Membrane cell electrolysis	1 ton caustic soda	30	120	Cell liquor	ton	1.4	Brine	2.1	-
							Electricity	215	
Evaporation & salt separation (diaphragm)	1 ton caustic soda	30	30	Caustic soda	ton	1	Cell liquor	1.4	2.66
							Electricity	76.7	
							Heat	81.7	

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./ yr.)
Evaporation & salt separation (membrane)	1 ton caustic soda	30	30	Caustic soda	ton	1	Cell liquor Electricity Heat	1.4 62 54.6	1.79
Utility in caustic soda plants	1 kgoe heat output	20	0	Heat	kgoe	1	Coal	1.3	-
Cement industry									
Wet process blending & grinding	1 ton clinker	20	1000	Slurry	ton	4	Limestone Electricity	1.9 2	-
Dry process blending & grinding	1 ton clinker	20	1200	Powder	ton	1.5	Limestone Electricity	1.49 3.5	-
Dry process blending & grinding (with pre-calcining)	1 ton clinker	20	1500	Preheated powder	ton	1.3	Limestone Electricity Coal Fuel oil	1.49 4 9.5 1	0.13
Wet process calcining	1 ton clinker	20	4000	Clinker	ton	1	Slurry Electricity Coal Fuel oil	4 4 139 2.3	1.51
Dry process calcining (without pre-calcining)	1 ton clinker	20	4000	Clinker	ton	1	Powder Electricity Coal Fuel oil	1.5 4 85 2.3	0.93
Dry process calcining (after pre-calcining)	1 ton clinker	20	3500	Clinker	ton	1	Preheated powder Electricity Coal Fuel oil	1.3 1.5 65 1.3	0.82
Improved dry process calcining (after pre-calcining)	1 ton clinker	20	3900	Clinker	ton	1	Preheated powder Electricity Coal Fuel oil	1.3 1.5 57 1.3	0.71
Blending, grinding & packing (wet process)	1 ton clinker	20	1000	Cement	ton	1.12	Clinker Electricity Fuel oil	1 3 2.5	-
Blending, grinding & packing (dry process)	1 ton clinker	20	1000	Cement	ton	1.12	Clinker Electricity Fuel oil	1 4 1.5	-
Improved blending, grinding & packing (dry process)	1 ton clinker	20	1200	Cement	ton	1.12	Clinker Electricity Fuel oil	1 2 1.2	-
Nitrogenous fertilizer industry									
Partial oxidation (coal-based)	1 ton urea	30	3000	Synthesis gas	ton	1.5	Coal Electricity Heat	3782 0.238 12	40.51
Partial oxidation (fuel oil-based)	1 ton urea	30	3000	Synthesis gas	ton	1.5	Fuel oil Electricity Heat	1780 5.95 25	13.52
Steam reforming (natural gas- based)	1 ton urea	30	2000	Synthesis gas	ton	1.5	Natural gas Electricity	1010 4	-
Steam reforming (naphtha- based)	1 ton urea	30	2000	Synthesis gas	ton	1.5	Naphtha Electricity	1270 4.96	-
Improved steam reforming (natural gas-based)	1 ton urea	30	2300	Synthesis gas	ton	1.5	Natural gas Electricity	900 3.5	-
Shift conversion & CO_2 removal	1 ton urea	30	1000	Purified synthesis gas	ton	1.25	Synthesis gas Electricity	1.5 66.2	-
Improved shift conversion & CO_2 removal	1 ton urea	30	1200	Purified synthesis gas	ton	1.25	Synthesis gas Electricity	1.5 57	-
Ammonia synthesis	1 ton urea	30	1500	Ammonia	ton	1.1	Purified synthesis gas Electricity	1.25 7.14	-
Improved ammonia synthesis	1 ton urea	30	1800	Ammonia	ton	1.1	Purified synthesis gas Electricity	1.25 6.1	-
Urea synthesis	1 ton urea	30	1000	Urea	ton	1	Ammonia Electricity	1.1 97.6	-
Improved urea synthesis	1 ton urea	30	1200	Urea	ton	1	Ammonia Electricity	1.1 75	-
Utility in fertilizer plants	1 kgoe heat output	20	0	Heat	kgoe	1	Coal	2.86	-

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./ yr.)
Soda ash industry									
Preparation, purification & carbonation of Brine (solvay process)	1 ton soda ash	30	100	Sodium bicarbonate	ton	1.4	Salt	1.6	0.05
							Electricity	18.67	
							Heat	3.04	
							Ammonia	0.2	
Preparation, purification & carbonation of Brine (dual process)	1 ton soda ash	30	120	Sodium bicarbonate	ton	1.4	Salt	1.6	0.005
							Electricity	5	
							Heat	0.28	
							Ammonia	0.2	
Preparation, purification & carbonation of Brine (Asahi process)	1 ton soda ash	30	130	Sodium bicarbonate	ton	1.4	Salt	1.6	0.03
							Electricity	22.6	
							Heat	1.74	
							Ammonia	0.2	
Calcination (solvay process)	1 ton soda ash	30	200	Soda ash	ton	1	Sodium bicarbonate	1.4	0.05
				Mother liquor	ton	0.3	Electricity	14.5	
							Heat	2.8	
Calcination (dual process)	1 ton soda ash	30	200	Soda ash	ton	1	Sodium bicarbonate	1.4	0.05
				Mother liquor	ton	0.3	Electricity	17.4	
							Heat	3	
Calcination (Asahi process)	1 ton soda ash	30	220	Soda ash	ton	1	Sodium bicarbonate	1.4	0.03
				Mother liquor	ton	0.3	Electricity	17.6	
							Heat	1.6	
Recovery of ammonia (solvay process)	1 ton soda ash	30	100	Ammonia	ton	0.2	Mother liquor	0.3	0.07
							Electricity	14.5	
							Heat	4.4	
Ammonium chloride section (dual process)	1 ton soda ash	30	120	Ammonia	tn	0.2	Mother liquor	0.3	0.02
							Electricity	99.3	
							Heat	1.2	
Recovery of ammonia (Asahi process)	1 ton soda ash	30	105	Ammonia	tn	0.2	Mother liquor	0.3	0.04
							Electricity	17.6	
							Heat	2.5	
Utility in soda ash plants	1 kgoe heat output	20	0	Heat	kgoe	1	Coal	1.3	-
Pulp and paper industry									
Pulp preparation (kraft process)	1 ton paper	30	150	Pulp	ton	2	Electricity	95	3.45
							Heat	60	
Pulp preparation (soda process)	1 ton paper	30	100	Pulp	ton	2	Electricity	58	3.89
							Heat	120	
Pulp preparation (secondary fiber pulping process)	1 ton paper	30	200	Pulp	ton	2	Electricity	26	1.66
							Heat	45	
Pulp preparation (kraft process & continuous digester)	1 ton paper	30	200	Pulp	ton	2	Electricity	88	3.19
							Heat	52	
Conventional bleaching (large mill)	1 ton paper	30	300	Bleached pulp	ton	1.43	Pulp	2	12.72
							Electricity	73	
							Heat	392	
Conventional bleaching (small mill)	1 ton paper	30	150	Bleached pulp	ton	1.43	Pulp	2	11.73
							Electricity	7	
							Heat	350	
Displacement bleaching	1 ton paper	30	250	Bleached pulp	ton	1.43	Pulp	2	1.62
							Electricity	22	
							Heat	50	
Stock preparation (large mill)	1 ton paper	30	120	Stock	ton	1.1	Bleached pulp	1.43	1.23
							Electricity	106	
							Heat	38	
Stock preparation (small mill)	1 ton paper	30	100	Stock	ton	1.1	Bleached pulp	1.43	1.53
							Electricity	30	
							Heat	47	
Conversion to paper (large mill)	1 ton paper	30	500	Paper	ton	1	Stock	1.1	8.47
							Electricity	134	
							Heat	261	
Conversion to paper (small mill)	1 ton paper	30	300	Paper	ton	1	Stock	1.1	4.87
							Electricity	38	
							Heat	150	
Conversion to paper (large mill with improved evaporator)	1 ton paper	30	550	Paper	ton	1	Stock	1.1	6.17
							Electricity	130	
							Heat	190	
Conversion to paper (small mill with improved evaporator)	1 ton paper	30	350	Paper	ton	1	Stock	1.1	4.38
							Electricity	34	
							Heat	135	
Utility in paper industry	1 kgoe heat output	20	0	Heat	kgoe	1	Coal	1.08	-

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./yr.)
Iron and steel industry									
Small size coke oven	1 ton crude	30	6000	Coke	toe	361.2	Coal	674.9	9.21
	steel			Coke gas	toe	12	Electricity	20.35	
Large size coke oven	1 ton crude	30	8000	Coke	toe	361.2	Coal	600	8.18
	steel			Coke gas	toe	48	Electricity	20.35	
Large size coke oven of	1 ton crude	30	9000	Coke	toe	361.2	Coal	570	7.77
Japan type	steel			Coke gas	toe	62	Electricity	15	
New coking + Coke	1 ton crude	30	10000	Coke	toe	361.2	Coal	550	7.50
wetting	steel			Coke gas	toe	66	Electricity	15	
Large size coke oven +	1 ton crude	30	10500	Coke	toe	361.2	Coal	580	7.91
DCQ	steel			Coke gas	toe	48			
Large size coke oven of	1 ton crude	30	11000	Coke	toe	361.2	Coal	500	6.82
Japan type + DCQ	steel			Coke gas	toe	62			
Sintering furnace	1 ton crude	20	4000	Sinter	ton	1.15	Coal	6.21	0.42
	steel						Oil	35	
							products		
							Iron Ore	1.03	
Large size sintering	1 ton crude	20	4000	Sinter	ton	1.15	Coal	5.1	0.34
furnace	steel						Oil	35	
							products		
							Iron Ore	1.03	
Advanced sintering	1 ton crude	20	4000	Sinter	ton	1.15	Coal	4.6	0.31
furnace	steel						Oil	35	
							products		
							Iron Ore	1.03	
Small size blast furnace	1 ton crude	20	4000	Pig iron from	ton	1.057	Coke	358.9	3.89
	steel			blast furnace			Coal	29.54	
				Blast furnace			Electricity	5.15	
				gas	toe	30	Sinter	1.15	
Large size blast furnace	1 ton crude	20	5000	Pig iron from	tn	1.057	Coke	291.1	3.89
	steel			blast furnace			Coal	55.94	
				Blast furnace			Electricity	4.7	
				gas	toe	72	Sinter	1.15	
Advanced blast furnace	1 ton crude	20	7000	Pig iron from	tn	1.057	Coke	266.9	2.60
	steel			blast furnace			Coal	54.64	
				Blast furnace			Electricity	4.3	
				gas	toe	102	Sinter	1.15	
Blast furnace + Wet TRT	1 ton crude	20	7500	Pig iron from	ton	1.057	Coke	266.9	2.50
	steel			blast furnace			Coal	51.94	
				Blast furnace			Sinter	1.15	
				gas	toe	102			
Blast furnace + Dry TRT	1 ton crude	20	8500	Pig iron from	ton	1.057	Coke	266.9	2.40
	steel			blast furnace			Coal	50.29	
				Blast furnace			Sinter	1.15	
				gas	toe	102			
Blast furnace + Wet TRT	1 ton crude	20	8700	Pig iron from	ton	1.057	Coke	176.9	4.60
+ 100kg CPI	steel			blast furnace			Coal	173.94	
				Blast furnace			Electricity	2.1	
				gas	toe	102	Sinter	1.15	
Blast furnace + Dry TRT	1 ton crude	20	9000	Pig iron from	ton	1.057	Coke	176.9	4.50
+ 100kg CPI	steel			blast furnace			Coal	172.29	
				Blast furnace			Electricity	2.1	
				gas	toe	102	Sinter	1.15	
Blast furnace + Wet TRT	1 ton crude	20	8900	Pig iron from	ton	1.057	Coke	107	5.20
+ 250kg CPI	steel			blast furnace			Coal	235.54	
				Blast furnace			Electricity	2.1	
				gas	toe	102	Sinter	1.15	
Blast furnace + Dry TRT	1 ton crude	20	9500	Pig iron from	ton	1.057	Coke	107	5.10
+ 250kg CPI	steel			blast furnace			Coal	233.89	
				Blast furnace			Electricity	2.1	
				gas	toe	102	Sinter	1.15	
COREX	1 ton crude	20	32000	Crude steel	ton	1	Coal	1300	4.20
	steel						Iron Ore	1.39	
DIOS	1 ton crude	20	31000	Crude steel	ton	1	Coal	1500	4.40
	steel						Iron Ore	1.39	
Small size ACF	1 ton crude	20	4000	Crude steel	ton	1	Electricity	130	0.34
	steel						Coal	95	
							Scrap iron	1	
Large size ACF	1 ton crude	20	4500	Crude steel	ton	1	Electricity	110	0.26
	steel						Coal	60	
							Scrap iron	1	

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./yr.)
DCF	1 ton crude steel	20	5000	Crude steel	ton	1	Electricity Coal Scrap iron	100 40 1	0.18
Advanced ACF	1 ton crude steel	20	6000	Crude steel	ton	1	Electricity Coal Scrap iron	100 50 1	0.19
Advanced DCF	1 ton crude steel	20	7500	Crude steel	ton	1	Electricity Coal Scrap iron	90 35 1	0.16
Small size converter	1 ton crude steel	20	4000	Crude steel	ton	1	Coal Electricity Oil products Pig iron	300 40 3.5 1.057	1.50
Large size converter	1 ton crude steel	20	5000	Crude steel	ton	1	Coal Electricity Oil products Pig iron	250 25 9 1.057	1.10
Converter with ZFG collection	1 ton crude steel	20	6000	Crude steel	ton	1	Coal Electricity Oil products Pig iron	200 14.5 9 1.057	0.90
Open hearth furnace	1 ton crude steel	20	4000	Crude steel	ton	1	Coal Electricity Oil products Pig iron	1300 10 18 1.057	4.20
Flow control 1	1 ton crude steel	1	0.01	Crude steel	ton	1	Crude steel – blast furnace	1	-
Flow control 2	1 ton crude steel	1	0.01	Crude steel	ton	1	Crude steel – electric arc furnace	1	-
Casting machine	1 ton crude steel	20	3000	Slab	ton	1	Coal Electricity Crude steel	140 0.82 1	0.62
Advanced casting	1 ton crude steel	20	3400	Slab	ton	1	Coal Electricity Crude steel	70 4.22 1	0.41
Continuous casting	1 ton crude steel	20	3100	Slab	ton	1	Coal Electricity Crude steel	30 4.5 1	0.20
Advanced continuous casting	1 ton crude steel	20	3700	Slab	ton	1	Coal Electricity Crude steel	10 2.81 1	0.06
Primary rolling machine	1 ton crude steel	20	4000	Finished steel	ton	1	Coal Electricity Slab	70 13.5 1	1.95
Large size primary rolling machine	1 ton crude steel	20	4200	Finished steel	ton	1	Coal Electricity Slab	60 10 1	1.80
Advanced heating furnace	1 ton crude steel	20	4900	Finished steel	ton	1	Coal Electricity Slab	50 10 1	1.60
Direct hot strip mill machine	1 ton crude steel	20	5000	Finished steel	ton	1	Coal Electricity Slab	25 9 1	0.90
Cotton textiles industry									
Spinning (ring frame - small mills)	1000 metres cotton textiles	30	400	Spinned yarn	1000 metres	1.5	Electricity	76	-
Spinning (ring frame - composite mills)	1000 metres cotton textiles	30	400	Spinned yarn	1000 metres	1.5	Electricity	42	-
Spinning (rotor technology)	1000 metres cotton textiles	30	400	Spinned yarn	1000 metres	1.5	Electricity	31	-
Weaving (non-automatic small mills)	1000 metres cotton textiles	30	200	Weaved yarn	1000 metres	1.25	Spinned yarn Electricity Heat	1.5 4 23	1.72
Weaving (improved small mills)	1000 metres cotton textiles	30	250	Weaved yarn	1000 metres	1.25	Spinned yarn Electricity Heat	1.5 4 14.3	1.07

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./yr.)
Weaving (non-automatic composite mills)	1000 metres cotton textiles	30	200	Weaved yarn	1000 metres	1.25	Spinned yarn Electricity Heat	1.5 18 23	1.72
Weaving (improved composite mills)	1000 metres cotton textiles	30	250	Weaved yarn	1000 metres	1.25	Spinned yarn Electricity Heat	1.5 14 14.3	1.07
Weaving (air jet looms)	1000 metres cotton textiles	30	300	Weaved yarn	1000 metres	1.25	Spinned yarn Electricity	1.5 21	-
Humidification & wet processing (small mills)	1000 metres cotton textiles	30	120	Cotton textiles	1000 metres	1	Weaved yarn Electricity Heat Fuel oil	1.25 15 12 32	1.17
Humidification & wet processing (improved small mills)	1000 metres cotton textiles	30	140	Cotton textiles	1000 metres	1	Weaved yarn Electricity Heat Fuel oil	1.25 13 8.7 25	0.88
Humidification & wet processing (composite mills)	1000 metres cotton textiles	30	120	Cotton textiles	1000 metres	1	Weaved yarn Electricity Heat Fuel oil	1.25 31 12 32	1.17
Humidification & wet processing (improved composite mills)	1000 metres cotton textiles	30	140	Cotton textiles	1000 metres	1	Weaved yarn Electricity Heat Fuel oil	1.25 27 8.7 25	0.88
Utility in textile plants	1 kgoe heat output	20	0	Heat	kgoe	1	Coal	2.3	-
Sugar industry									
Juice extraction & clarification (existing milling & double sulfitation process)	1 ton sugar	30	40	Juice Steam	ton kgoe	2 200	Sugarcane Electricity Heat	3 37 84	2.73
Juice extraction & clarification (improved sulfitation process)	1 ton sugar	30	45	Juice Steam	ton kgoe	2 220	Sugarcane Electricity Heat	3 31 80	2.60
Evaporation (existing process)	1 ton sugar	30	40	Sugar slurry	ton	1.5	Juice Electricity Heat	2 12 112	3.70
Evaporation (falling film process)	1 ton sugar	30	45	Sugar slurry	ton	1.5	Juice Electricity Heat	2 10 90	2.92
Crystallizaton (existing process)	1 ton sugar	30	40	Sugar crystals	ton	1.25	Sugar slurry Electricity Heat	1.5 14 140	4.54
Crystallizaton (improved process)	1 ton sugar	30	45	Sugar crystals	ton	1.25	Sugar slurry Electricity Heat	1.5 12 125	3.98
Centrifuging, drying, grading & packing (batch centrifuge)	1 ton sugar	30	20	Sugar	ton	1	Sugar crystals Electricity Heat	1.25 0.9 37	1.20
Centrifuging, drying, grading & packing (continuous centrifuge)	1 ton sugar	30	23	Sugar	ton	1	Sugar crystals Electricity Heat	1.25 0.7 37	1.20
Cogeneration (existing)	1 kgoe steam input	20	0	Heat Electricity	kgoe kgoe	1.8 0.16	Steam	1	-
Cogeneration (extraction cum back pressure condensing)	1 kgoe steam input	20	0	Heat Electricity	kgoe kgoe	1.8 0.18	Steam	1	-
Dual fuel cogeneration	1 kgoe steam input	20	0	Heat Electricity	kgoe kgoe	1.8 0.25	Steam Coal	1 0.2	-
Other industries									
Industry - other – biomass	1	1	20	Ind - others - biomass	toe	1	Bio energy	1000	4.18
Industry - other - commercial fuels	1	1	1000	Industry - others - commercial fuels	index	1	Coal Natural gas Oil products Electricity	5532480 2441680 1596960 6211325	98215

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./yr.)
New industry - other - commercial fuels	1	1	700	Industry - others - commercial fuels	index	1	Coal Natural gas Oil products Electricity	316240 2774180 137872 9281255	22553
Commercial sector									
Commercial sector devices - existing mix	1 Million US$95	1	1	Commercial/ service value added	Million US$95	1	Electricity Natural gas Diesel Biomass	43600 4350 20540 23180	192.1
Commercial sector devices - new mix1	1 Million US$95	1	1	Commercial/ service value added	Million US$95	1	Electricity Natural gas Diesel Biomass	49390 6400 26060 10410	166.1
Commercial sector devices - new mix2	1 Million US$95	1	1	Commercial/ service value added	Million US$95	1	Electricity Natural gas Diesel Biomass	54680 9930 30240 4480	166.1
Transport sector									
Cargo aircraft	1 aircraft	15	500000	Air freight	million-km-ton	15	ATF	1335000	16671
New cargo aircraft	1 aircraft	15	500000	Air freight	million-km-ton	15	ATF	1050000	13191
Diesel locomotive	1 train	15	375000	Rail freight	million-km-ton	49	Diesel	200900	10095
Electric locomotive	1 train	15	500000	Rail freight	million-km-ton	50	Electricity	126500	-
New electric locomotive	1 train	15	500000	Rail freight	million-km-ton	50	Electricity	100000	-
Steam locomotive	1 train	15	250000	Rail freight	million-km-ton	50	Coal	348000	4372
Heavy truck	1 truck	10	25000	Road freight	million-km-ton	0.1152	Diesel	4840	162.1
New heavy truck	1 truck	10	25000	Road freight	million-km-ton	0.1152	Diesel	4035	135.2
Light truck	1 truck	10	15000	Road freight	million-km-ton	0.0864	Diesel	4147.2	121.6
New light truck	1 truck	10	15000	Road freight	million-km-ton	0.0864	Diesel	3456	101.3
Ship	1 ship	10	375000	Water freight	million-km-ton	15	Diesel	1200000	75377
New ship	1 ship	10	375000	Water freight	million-km-ton	15	Diesel	900000	56532
Aircraft	1 aircraft	15	500000	Air passenger	million-km-persons	15	ATF	1335000	16671
New aircraft	1 aircraft	15	500000	Air passenger	million-km-persons	15	ATF	1050000	13191
Diesel locomotive	1 train	15	375000	Rail passenger	million-km-persons	49	Diesel	200900	10095
Electric locomotive	1 train	15	500000	Rail passenger	million-km-persons	50	Electricity	126500	-
New electric locomotive	1 train	15	500000	Rail passenger	million-km-persons	50	Electricity	100000	-
Steam locomotive	1 train	15	250000	Rail passenger	million-km-persons	50	Coal	348000	4372
Bus-CNG	1 bus	10	15000	Road passenger	million-km-persons	2.592	Natural gas	10108.8	253.9
New bus-CNG	1 bus	10	45000	Road passenger	million-km-persons	2.592	Natural gas	8553.6	214.9
Bus-diesel	1 bus	10	15000	Road passenger	million-km-persons	2.592	Diesel	12960	325.6
New bus-diesel	1 bus	10	15000	Road passenger	million-km-persons	2.592	Diesel	9849.6	247.5
Electric bus	1 bus	10	45000	Road passenger	million-km-persons	2.592	Electricity	7776	-
Cars, vans & jeeps	1 car	7	6250	Road passenger	million-km-persons	0.027	Gasoline	864	21.7

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./yr.)
New cars	1 car	7	6250	Road passenger	million-km-persons	0.027	Gasoline	675	16.9
Electric cars	1 car	7	9250	Road passenger	million-km-persons	0.027	Electricity	500	-
Three-wheeler - gasoline	1 vehicle	7	1500	Road passenger	million-km-persons	0.054	Gasoline	1080	27.1
Three-wheeler - kerosene	1 vehicle	7	1500	Road passenger	million-km-persons	0.054	Kerosene	2160	54.3
Two-wheelers	1 scooter	7	500	Road passenger	million-km-persons	0.01296	Gasoline	50.6	1.27
New two-wheelers	1 scooter	7	500	Road passenger	million-km-persons	0.01296	Gasoline	32.4	0.81
Residential sector									
Biomass stove	1 stove	5	2.5	Cooking - rural	toe	0.144	Biomass	1296	5.43
Coal stove	1 stove	5	12.5	Cooking - rural	toe	0.144	Coal	288	1.21
Electric stove	1 stove	5	50	Cooking - rural	toe	0.144	Electricity	158	-
Kerosene stove	1 stove	5	25	Cooking - rural	toe	0.144	Kerosene	216	0.90
LPG stove	1 stove	5	125	Cooking - rural	toe	0.144	LPG	172.8	0.72
New LPG stove	1 stove	5	130	Cooking - rural	toe	0.144	LPG	158	0.66
Solar cooker	1 stove	5	25	Cooking - rural	toe	0.144	Solar	0	-
Incandescent lamp (bulb)	1 bulb	1	0.5	Lighting – rural	billion-lumen-hr	0.001	Electricity	12	-
CFL	1 lamp	1	3.25	Lighting – rural	billion-lumen-hr	0.002	Electricity	5	-
Fl. tube	1 tube	1	3.25	Lighting – rural	billion-lumen-hr	0.0016	Electricity	5.28	-
Kerosene lamp	1 lamp	1	0.75	Lighting – rural	billion-lumen-hr	0.0003	Kerosene	180	0.75
Biomass stove	1 stove	5	2.5	Cooking - urban	toe	0.144	Bio energy	1296	5.43
Coal stove	1 stove	5	12.5	Cooking - urban	toe	0.144	Coal	288	1.21
Electric stove	1 stove	5	50	Cooking - urban	toe	0.144	Electricity	158	-
Kerosene stove	1 stove	5	25	Cooking - urban	toe	0.144	Kerosene	216	0.90
LPG stove	1 stove	5	125	Cooking - urban	toe	0.144	LPG	172.8	0.72
New LPG stove	1 stove	5	125	Cooking - urban	toe	0.144	LPG	158	0.66
Solar cooker	1 stove	5	25	Cooking - urban	toe	0.144	Solar	0	-
Incandescent lamp (bulb)	1 bulb	1	0.5	Lighting – urban	billion-lumen-hr	0.001	Electricity	12	-
CFL	1 lamp	1	3.25	Lighting – urban	billion-lumen-hr	0.002	Electricity	5	-
Fl. tube	1 tube	1	3.25	Lighting – urban	billion-lumen-hr	0.0016	Electricity	5.28	-
Kerosene lamp	1 lamp	1	0.75	Lighting – urban	billion-lumen-hr	0.0003	Kerosene	180	0.75
Fan	1 fan	5	12.5	Fan	1000 no.	0.001	Electricity	15	-
Refrigerator	1 refrigerator	7	300	Refrigerator	1000 no.	0.001	Electricity	80	-
TV	1 tv	7	125	TV	1000 no.	0.001	Electricity	9	-
Washing m/c	1 m/c	7	100	Washing m/c	1000 no.	0.001	Electricity	50	-
Air conditioner	1 a/c	10	1250	Air conditioner	1000 no.	0.001	Electricity	425	-
Other electric appliances	1 appliance	3	25	Other appliances	toe	0.005	Electricity	4	-
Oil refining sector									
Petroleum refinery-1	1 ton crude throughput	30	200	Petroleum products	kgoe	960	Crude Oil	1022	-
Petroleum refinery-2	1 ton crude throughput	30	170	Petroleum products	kgoe	970	Crude Oil	1022	-
Petroleum refinery-3	1 ton crude throughput	30	175	Petroleum products	kgoe	985	Crude Oil	1022	-

d.u. = Device Unit

Device	Device unit	Life (yr.)	Fixed cost (95US$/d.u.)	Service	Service unit	Specific service output (service unit/d.u./yr.)	Energy	Specific energy input (kgoe/d.u./yr.)	NO_x factor (kg-NO_x/ d.u./yr.)
Electricity generation sector									
Biomass power plant	1 MW	20	950000	Electricity	kgoe	753360	Biomass	2508689	10505
Biomass power plant –advanced	1 MW	20	1050000	Electricity	kgoe	753360	Biomass	1880000	7873
Pulverized bed coal power plant (existing)	1 MW	30	1125000	Electricity	kgoe	753360	Coal	2322000	29171
Pulverized bed coal power plant (improved)	1 MW	30	1740000	Electricity	kgoe	753360	Coal	1680000	21105
PFBC power plant	1 MW	30	1175000	Electricity	kgoe	753360	Coal	2116942	26595
AFBC power plant	1 MW	30	1275000	Electricity	kgoe	753360	Coal	2282681	28677
Diesel generator	1 MW	15	775000	Electricity	kgoe	753360	Diesel	2576491	21578
Gas turbine	1 MW	20	850000	Electricity	kgoe	753360	Natural gas	2184744	13723
CCGT	1 MW	20	600000	Electricity	kgoe	753360	Natural gas	1657392	10411
CCGT – advanced	1 MW	20	650000	Electricity	kgoe	753360	Natural gas	1257392	7898
IGCC power plant (coal)	1 MW	20	2000000	Electricity	kgoe	753360	Coal	1457392	18309
IGCC power plant (biomass)	1 MW	20	2000000	Electricity	kgoe	753360	Biomass	1457392	6103
CHP plant	1 MW	20	2000000	Electricity Heat	kgoe kgoe	753360 650000	Natural gas	1600000	10050
Proton exchange membrane fuel cell	1 MW	20	1100000	Electricity	kgoe	753360	Natural gas	1650000	10364
Phosphoric acid fuel cell	1 MW	20	1500000	Electricity	kgoe	753360	Natural gas	2000000	12563
Solid oxide fuel cell	1 MW	20	1620000	Electricity	kgoe	753360	Natural gas	1160000	7286
Solid oxide fuel cell coupled with CCGT	1 MW	20	1800000	Electricity	kgoe	753360	Natural gas	1020000	6407
Geothermal power	1 MW	20	1250000	Electricity	kgoe	753360	Geothermal	753360	-
Hydro power plant	1 MW	60	1000000	Electricity	kgoe	753360	Water energy	753360	-
Nuclear power plant	1 MW	40	2200000	Electricity	kgoe	753360	Nuclear	2000000	-
Oil fired power plant	1 MW	30	1250000	Electricity	kgoe	753000	Oil products	2213820	18541
Oil fired power (improved)	1 MW	30	1250000	Electricity	kgoe	753360	Oil products	1695060	14196
Solar PV	1 MW	20	4000000	Electricity	kgoe	753360	Solar	753360	-
Wind power	1 MW	20	1000000	Electricity	kgoe	753360	Wind energy	753360	-

d.u. = Device Unit

Note: Data for existing technologies have been estimated from numerous domestic publications and estimation methodology described in Chap. 3. These are average estimates for India. Data for future technologies are based on international sources. Data for fixed costs of some technologies are not accurate.

Appendix I: Characteristics of technologies in AIM-Japan

Table I.1. Characteristics of technologies in industrial sector

Energy Device	Device Unit	Fixed Cost (JPY)	Life (Years)	Specific Service		Specific Energy Input		Material Use	NOx (kg/yr./d.u.)
Industrial Sector - Steel									
Without coal wet adjust eqpt.	1t-c.s.	-	1	Adjusted coke	36.81 [a]	Coal	54.41 [a]	0.05	0.000
						Utility	0.5 [a]	0	
Coke wet adjustment equipment	1t-c.s.	1500	30	Adjusted coke	36.81 [a]	Coal	54.41 [a]	0.05	0.000
						Utility	0 [a]	0	
Without automatic combustion ctrl.	1t-c.s.	-	1	Heat for coke oven	3.74 [a]	Utility	3.96 [a]	0	0.000
With automatic combustion control	1t-c.s.	100	30	Heat for coke oven	3.74 [a]	Utility	3.74 [a]	0	0.000
Conventional coke oven	1t-c.s.	5000	30	Hot coke	36.81 [a]	Adjusted coke	36.81 [a]	0	1.161
				COG	9 [a]	Heat for coke oven	3.74 [a]	0	
						Electricity	0.23 [a]	0	
Next generation coke oven	1t-c.s.	5000	30	Hot coke	36.81 [a]	Adjusted coke	36.81 [a]	0	0.797
				COG	9 [a]	Heat for coke oven	2.96 [a]	0	
						Electricity	0.23 [a]	0	
Cnv. coke oven + COG latent heat recovery	1t-c.s.	5800	30	Hot coke	36.81 [a]	Adjusted coke	36.81 [a]	0	0.000
				COG	9 [a]	Heat for coke oven	3.74 [a]	0	
				Waste gas and heat	0.18 [a]	Electricity	0.23 [a]	0	
Next gnr. coke oven + COG latent heat recovery	1t-c.s.	5800	30	Hot coke	36.81 [a]	Adjusted coke	36.81 [a]	0	0.000
				COG	9 [a]	Heat for coke oven	2.96 [a]	0	
				Waste gas and heat	0.18 [a]	Electricity	0.23 [a]	0	
Coke wet type quenching	1t-c.s.	5200	30	Coke (in steel)	36.81 [a]	Hot coke	36.81 [a]	0	0.000
Coke dry type quenching	1t-c.s.	6500	30	Coke (in steel)	36.81 [a]	Hot coke	36.81 [a]	0	0.000
				Electricity from waste heat	0.29 [a]				
				Waste gas and heat	0.77 [a]				
COG for steel industry	100Mcal	-	1	COG potential	1 [a]	COG	1	0	0.000
				Waste gas and heat	1 [a]				
COG for other industries	100Mcal	-	1	COG potential	1 [a]	COG	1	0	0.000
				Gas for other process	1 [a]	Coal for other process	1		
Coke from coke furnace	100Mcal	-	1	Coke	1 [a]	Coke (in steel)	1 [a]	0	0.000
Purchased coke	100Mcal	-	1	Coke	1 [a]	Coke	1 [a]	0	
Conventional igniter of sintering furnace	100Mcal	-	1	Heat for sinter furnace	0.48 [a]	Utility	0.88 [a]	0	0.000
						Electricity	0.41 [a]	0	
Automatic ingiter of sintering furnace	100Mcal	100	30	Heat for sinter furnace	0.48 [a]	Utility	0.48 [a]	0	0.000
						Electricity	0.41 [a]	0	
Sintering furnace	1t-c.s.	5000	30	Sinter	1.34 [b]	Coal	1.02 [a]	0	0.864
						Iron Ore	1.41 [b]	1	
						Coke	3.32 [a]	0	
						Heat for sinter furnace	0.48 [a]	0	
Sintering frn. + Mainly waste heat recovery	1t-c.s.	6500	30	Sinter	1.34 [b]	Coal	1.02 [a]	0	0.864
				Waste gas and heat	0.27 [a]	Iron Ore	1.41 [b]	1	
						Coke	3.32 [a]	0	
						Heat for sinter furnace	0.48 [a]	0	
Sintering frn. + Cooler waste heat recovery	1t-c.s.	8000	30	Sinter	1.34 [b]	Coal	1.02 [a]	0	0.864
				Waste gas and heat	0.6 [a]	Iron Ore	1.41 [b]	1	
						Coke	3.32 [a]	0	
						Heat for sinter furnace	0.48 [a]	0	
Sintering frn. + Mainly/Cooler waste heat recovery	1t-c.s.	9500	30	Sinter	1.34 [b]	Coal	1.02 [a]	0	0.864
				Waste gas and heat	0.87 [a]	Iron Ore	1.41 [b]	1	
						Coke	3.32 [a]	0	
						Heat for sinter furnace	0.48 [a]	0	

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=t/year/d.u., d.u.=device unit, c.s.=crude steel

Table I.1. Characteristics of technologies in industrial sector (continued)

Energy Device	Device Unit	Fixed Cost (JPY)	Life (Years)	Specific Service		Specific Energy Input		Mate-rial Use	NOx (kg/yr./d.u.)
Without waste plastic	1t-c.s.	-	30	Coke with plastic	33.57 [a]	Coke	33.57 [a]	0	0.000
With waste plastic	1t-c.s.	3000	30	Coke with plastic	33.57 [a]	Coke	30.81 [a]	0	0.000
Blast furnace	1t-c.s.	5000	30	Pig iron	1.07 [b]	Coke with plastic	33.57 [a]	0	0.039
				BFG	13.1 [a]	Coal	4.71 [a]	0	
				Electricity from	0.001 [a]	Sinter	1.34 [b]	1	
				waste heat		Utility	1.81 [a]	0	
Blast furnace + Wet top-pressure	1t-c.s.	7100	30	Pig iron	1.07 [b]	Coke with plastic	33.57 [a]	0	0.000
recovery turbin				BFG	13.1 [a]	Coal	4.71 [a]	0	
				Electricity from	0.39 [a]	Sinter	1.34 [b]	1	
				waste heat		Utility	1.81 [a]	0	
Blast furnace + Dry top-pressure	1t-c.s.	7600	30	Pig iron	1.07 [b]	Coke with plastic	33.57 [a]	0	0.000
recovery turbin				BFG	13.1 [a]	Coal	4.71 [a]	0	
				Electricity from	0.45 [a]	Sinter	1.34 [b]	1	
				waste heat		Utility	1.81 [a]	0	
BFG for steel industry	100Mcal	-	1	BOG potential	1 [a]	BFG	1 [a]	0	0.000
				Waste gas and heat	1 [a]				
BFG for other industries	100Mcal	-	1	BOG potential	1 [a]	BFG	1 [a]	0	0.000
				Gas for other	1 [a]	Coal for other	1		
				process		process			
LDF	1t-c.s.	15000	30	Crude steel (BOF)	1 [b]	Pig iron	1.07 [b]	1	0.000
				LDG	0.001 [a]	Scrap steel	0.07 [b]	1	
						Utility	0.18 [a]	0	
						Electricity	0.8 [a]	0	
LDF + Cnv. LDG recovery	1t-c.s.	16960	30	Crude steel (BOF)	1 [b]	Pig iron	1.07 [b]	1	0.000
				LDG	2.07 [a]	Scrap steel	0.07 [b]	1	
						Utility	0.18 [a]	0	
						Electricity	0.8 [a]	0	
LDF + Closed LDG recovery	1t-c.s.	17100	30	Crude steel (BOF)	1 [b]	Pig iron	1.07 [b]	1	0.000
				LDG	2.27 [a]	Scrap steel	0.07 [b]	1	
						Utility	0.18 [a]	0	
						Electricity	0.8 [a]	0	
LDF + Cnv. LDG recovery +	1t-c.s.	19710	30	Crude steel (BOF)	1 [b]	Pig iron	1.07 [b]	1	0.000
Latent recovery				LDG	2.07 [a]	Scrap steel	0.07 [b]	1	
				Waste gas and heat	2.5 [a]	Utility	0.18 [a]	0	
						Electricity	0.8 [a]	0	
LDF + Closed LDG recovery +	1t-c.s.	19850	30	Crude steel (BOF)	1 [b]	Pig iron	1.07 [b]	1	0.000
Latent recovery				LDG	2.27 [a]	Scrap steel	0.07 [b]	1	
				Waste gas and heat	2.74 [a]	Utility	0.18 [a]	0	
						Electricity	0.8 [a]	0	
LDG for steel industry	100Mcal	-	1	LDG potential	1 [a]	LDG	1 [a]	0	0.000
				Waste gas and heat	1 [a]				
LDG for other industries	100Mcal	-	1	LDG potential	1 [a]	LDG	1 [a]	0	0.000
				Gas for other	1 [a]	Coal for other	1		
				process		process			
Without scrap pre-heat	1t-c.s.	-	1	Hot scrap	1.05 [b]	Scrap steel	1.05 [b]	1	0.000
						Electricity	0.19 [a]	0	
Scrap pre-heat	1t-c.s.	650	30	Hot scrap	1.05 [b]	Scrap steel	1.05 [b]	1	0.000
						Electricity	0 [a]	0	
AC electric furnace	1t-c.s.	4200	30	Crude steel (EF)	1 [b]	Hot scrap	1.05 [b]	1	0.141
						Electricity	3.73 [a]	0	
						Utility	0.6 [a]	0	
DC electric furnace	1t-c.s.	5250	30	Crude steel (EF)	1 [b]	Hot scrap	1.05 [b]	1	0.141
						Electricity	3.41 [a]	0	
						Utility	0.6 [a]	0	
DIOS	1t-c.s.	22500	30	Crude steel (DIOS)	1 [b]	Iron Ore	1.41 [b]	1	0.797
				COG	9.02 [a]	Coal	60.24 [a]	0	
				BFG	13.1 [a]	Utility	2.06 [a]	0	
				LDG	2.07 [a]	Electricity	1.68 [a]	0	
Crude steel (LDF)	1t-c.s.	-	1	Crude steel	1 [b]	Crude steel (BOF)	1 [b]	1	0.000
Crude steel (DIOS)	1t-c.s.	-	1	Crude steel	1 [b]	Crude steel (DIOS)	1 [b]	1	0.000
Crude steel (Electric furnace)	1t-c.s.	-	1	Crude steel	1 [b]	Crude steel (EF)	1 [b]	1	0.000
Ingot making	1t-c.s.	5400	30	Hot slab1	0.987 [b]	Crude steel	1 [b]	1	0.000
						Electricity	0.42 [a]	0	
						Utility	1.93 [a]	0	
Continuous caster	1t-c.s.	4500	30	Hot slab1	0.987 [b]	Crude steel	1 [b]	1	0.000
						Electricity	0.14 [a]	0	
						Utility	0.13 [a]	0	

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=t/year/d.u., d.u.=device unit, c.s.=crude steel

Table I.1. Characteristics of technologies in industrial sector (continued)

Energy Device	Device Unit	Fixed Cost (JPY)	Life (Years)	Specific Service		Specific Energy Input		Mate-rial Use	NOx (kg/yr./d.u.)
Without hot charge rolling	1t-c.s.	-	10	Hot slab2	0.987 [b]	Hot slab1	0.987 [b]	1	0.000
						Utility	0.9 [a]	0	
Hot charge rolling	1t-c.s.	1000	30	Hot slab2	0.987 [b]	Hot slab1	0.987 [b]	1	0.000
						Utility	0 [a]	0	
Hot direct rolling	1t-c.s.	2000	30	Hot slab3	0.987 [b]	Hot slab1	0.987 [b]	1	0.000
						Utility	0 [a]	0	
Conventinal hearting furnace	1t-c.s.	2400	30	Hot slab3	0.987 [b]	Hot slab2	0.987 [b]	1	0.035
						Utility	2.1 [a]	0	
High efficiency hearting furnace	1t-c.s.	3000	30	Hot slab3	0.987 [b]	Hot slab2	0.987 [b]	1	0.028
						Utility	1.71 [a]	0	
Rolling process	1t-c.s.	-	1	Hot rolled steel pruducts 1	0.981 [b]	Hot slab3	0.987 [b]	1	0.000
						Utility	0.54 [a]	0	
						Electricity	0.88 [a]	0	
Conventional hot rolling process	1t-c.s.	5000	30	Hot rolled steel pruducts 2	0.981 [b]	Hot slab3	0.987 [b]	1	0.009
						Utility	0.54 [a]	0	
						Electricity	0.82 [a]	0	
High efficiency hot rolling process	1t-c.s.	5000	30	Hot rolled steel pruducts 2	0.981 [b]	Hot slab3	0.987 [b]	1	0.004
						Utility	0.24 [a]	0	
						Electricity	0.82 [a]	0	
Conventional coil rolling	1t-c.s.	5000	30	Hot rolled steel pruducts 3	0.981 [b]	Hot rolled steel pruducts 2	0.981 [b]	1	0.000
						Electricity	0.06 [a]	0	
High efficiency coil rolling	1t-c.s.	5000	30	Hot rolled steel pruducts 3	0.981 [b]	Hot rolled steel pruducts 2	0.981 [b]	1	0.000
						Electricity	0 [a]	0	
Hot rolled sheets	1 t	-	1	Hot rolled steel prod	1 [b]	Hot rolled steel pruducts 3	1 [b]	1	0.000
Hot rolled slab	1 t	-	1	Hot rolled steel prod	1 [b]	Hot rolled steel pruducts 1	1 [b]	1	0.000
Conventional Continuous Annealing lines	1t-c.s.	8000	30	Cold rolled steel production	1.004 [b]	Hot rolled steel pruducts 3	0.981 [b]	1	0.083
						Electricity	1.94 [a]	0	
						Utility	4.45 [a]	0	
High Efficiency Continuous Annealing lines	1t-c.s.	10000	30	Cold rolled steel production	1.004 [b]	Hot rolled steel pruducts 3	0.981 [b]	1	0.066
						Electricity	1.94 [a]	0	
						Utility	3.55 [a]	0	
Purchased electricity	100Mcal	-	1	Electricity	1 [a]	Electricity	1 [a]	0	0.000
Industrial-Owned power gnr.	100Mcal	-	1	Electricity	1 [a]	Endgenous ele.	1 [a]	0	0.000
Conventional Industrial-owned	100Mcal	1615	1	Endgenous ele.	1 [a]	Utility	3.23 [a]	0	0.088
Repowering	100Mcal	1723	1	Endgenous ele.	1 [a]	Utility	2.56 [a]	0	0.070
Conbined cycle power plant	100Mcal	2019	1	Endgenous ele.	1 [a]	Town Gas	2 [a]	0	0.055
Solar	100Mcal	92180	1	Endgenous ele.	1 [a]	Solar	2.62 [a]	0	0.000
Recover	100Mcal	0	1	Endgenous ele.	1 [a]	Electricity from waste heat	1 [a]	0	0.000
Coal	100Mcal	-	1	Utility	1 [a]	Coal	1 [a]	0	0.000
Oil	100Mcal	-	1	Utility	1 [a]	Oil Products	1 [a]	0	0.000
Gas	100Mcal	-	1	Utility	1 [a]	Town Gas	1 [a]	0	0.000
Recover	100Mcal	-	1	Utility	1 [a]	Waste gas and heat	1 [a]	0	0.000
Industrial Sector - Cement									
Tube mill	1 t	2875	30	Raw meal	1 [b]	Limestone	1.15 [b]	1	0.000
						Electricity	0.28 [a]	0	
Vertical mill	1 t	1917	30	Raw meal	1 [b]	Limestone	1.15 [b]	1	0.000
						Electricity	0.22 [a]	0	
L/DB	1 t	2208	30	Hot clinker 1	1 [b]	Raw meal	1 [b]	1	0.952
				Waste heat	0.437 [a]	Coal	9.72 [a]	0	
						Electricity	0.257 [a]	0	
NSP/SP	1 t	2760	30	Hot clinker 1	1 [b]	Raw meal	1 [b]	1	0.672
				Waste heat	0.437 [a]	Coal	6.86 [a]	0	
						Electricity	0.257 [a]	0	
Kiln burner	1 t	100	30	Hot clinker 2	1 [b]	Hot clinker 1	1 [b]	1	0.000
						Coal	0.02 [a]	0	
Improved kiln burner	1 t	100	30	Hot clinker 2	1 [b]	Hot clinker 1	1 [b]	1	0.000
						Coal	0 [a]	0	
Fludized bed sintering frn.	1 t	4140	30	Portalnd clinker	1 [b]	Raw meal	1 [b]	1	0.570
				Waste heat	0.287 [a]	Coal	5.82 [a]	0	
						Electricity	0.257 [a]	0	

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=t/year/d.u., d.u.=device unit, c.s.=crude steel

Table I.1. Characteristics of technologies in industrial sector (continued)

Energy Device	Device Unit	Fixed Cost (JPY)	Life (Years)	Specific Service		Specific Energy Input		Mate-rial Use	NOx (kg/yr. /d.u.)
Conventional kiln cooler	1 t	-	30	Portalnd clinker	1 [b]	Hot clinker 2	1 [b]	1	0.000
						Coal	0.35 [a]	0	
High efficiency kiln cooler	1 t	455	30	Portalnd clinker	1 [b]	Hot clinker 2	1 [b]	1	0.000
						Coal	0 [a]	0	
Exported portland clinker	1 t	-	1	Exporting clinker	1 [b]	Portalnd clinker	1 [b]	1	0.000
Mixed portland cement's material	1 t	-	1	Portalnd cement	1 [b]	Portalnd clinker	0.95 [b]	0	0.000
						Blast furnace slag	0.05 [b]	1	
Mixed blast furnace cement's material	1 t	-	1	Blast furnace cement	1 [b]	Portalnd clinker	0.55 [b]	0	0.000
						Blast furnace slag	0.45 [b]	1	
Mixed fly ash cement's material	1 t	-	1	Fly ash cement	1 [b]	Portalnd clinker	0.85 [b]	0	0.000
						Fly ash	0.15 [b]	1	
Flow control (Portland cement)	1 t	-	1	Cement before finish	1 [b]	Portalnd cement	1 [b]	1	0.000
Flow control (Blast furnace cement)	1 t	-	1	Cement before finish	1 [b]	Blast furnace cement	1 [b]	1	0.000
Flow control (Fry ash cement)	1 t	300	1	Cement before finish	1 [b]	Fly ash cement	1 [b]	1	0.000
Without pre-grinder	1 t	-	30	Grinded cement	1 [b]	Cement before finish	1 [b]	1	0.000
						Electricity	0.069 [a]	0	
With pre-grinder	1 t	833	30	Grinded cement	1 [b]	Cement before finish	1 [b]	1	0.000
						Electricity	0 [a]	0	
Ball mill	1 t	2875	30	Cement	1 [b]	Grinded cement	1 [b]	1	0.000
						Electricity	0.354 [a]	0	
Vertical mill	1 t	2917	30	Cement	1 [b]	Cement before finish	1 [b]	1	0.000
						Electricity	0.259 [a]	0	
Other sector	1 t	-	1	Cement others	1 [b]	Electricity	0.063 [a]	1	0.000
Industrial-owned power gnr.	100Mcal	1615	30	Endgenous ele.	1 [a]	Utility	3.23 [a]	0	0.088
Repowering	100Mcal	1723	30	Endgenous ele.	1 [a]	Utility	2.56 [a]	0	0.070
Combind cycle generation	100Mcal	2019	30	Endgenous ele.	1 [a]	Utility	2 [a]	0	0.055
Photovoltanic	100Mcal	92180	30	Endgenous ele.	1 [a]	Solar	2.62 [a]	0	0.000
Heat recovery generation	100Mcal	8640	30	Endgenous ele.	1 [a]	Waste heat	2.62 [a]	0	0.000
Purchased electricity	100Mcal	-	1	Electricity	1 [a]	Electricity	1 [a]	0	0.000
Industrial-owned power gnr.	100Mcal	-	1	Electricity	1 [a]	Endgenous ele.	1 [a]	0	0.000
Coal	100Mcal	-	1	Utility	1 [a]	Coal	1 [a]	0	0.000
Oil	100Mcal	-	1	Utility	1 [a]	Oil Products	1 [a]	0	0.000
Town gas	100Mcal	-	1	Utility	1 [a]	Town Gas	1 [a]	0	0.000
Industrial Sector - Petrochemicals									
Conventional Naptha cracking device	1 t	76800	30	Ethylene	1 [b]	Naptha	439 [a]	0.8	11.897
				Recovered steam	4.66 [a]	LPG	37.5 [a]	0.8	
				Subproduct Gas	95.5 [a]	Direct Heat	0.17 [a]	0	
						Electricity	71.6 [a]	0	
High performance. Naptha cracking device	1 t	96000	30	Ethylene	1 [b]	Naptha	439 [a]	0.8	11.572
				Recovered steam	4.66 [a]	LPG	37.5 [a]	0.8	
				Subproduct Gas	95.5 [a]	Direct Heat	0.17 [a]	0	
						Electricity	56.6 [a]	0	
Naptha attached cracking device	1 t	120000	30	Ethylene	1 [b]	Naptha	439 [a]	0.8	10.430
				Recovered steam	4.66 [a]	LPG	37.5 [a]	0.8	
				Subproduct Gas	95.5 [a]	Direct Heat	0.11 [a]	0	
						Electricity	4.04 [a]	0	
Cnv. Naptha cracking + Electricity recovery	1 t	76800	30	Ethylene	1 [b]	Naptha	439 [a]	0.8	11.897
				Recovered steam	4.66 [a]	LPG	37.5 [a]	0.8	
				Recovered electricity	1.9 [a]	Direct Heat	0.17 [a]	0	
				Subproduct Gas	95.5 [a]	Electricity	71.6 [a]	0	
High prf. Naptha cracking + Electricity recovery	1 t	96000	30	Ethylene	1 [b]	Naptha	439 [a]	0.8	11.572
				Recovered steam	4.66 [a]	LPG	37.5 [a]	0.8	
				Recovered electricity	1.9 [a]	Direct Heat	0.17 [a]	0	
				Subproduct Gas	95.5 [a]	Electricity	56.6 [a]	0	
Naptha attached cracking + Electricity recovery	1 t	120000	30	Ethylene	1 [b]	Naptha	439 [a]	0.8	10.430
				Recovered steam	4.66 [a]	LPG	37.5 [a]	0.8	
				Recovered electricity	1.9 [a]	Direct Heat	0.11 [a]	0	
				Subproduct Gas	95.5 [a]	Electricity	4.04 [a]	0	
Conventional LDPE manufacturing device	1 t	32000	30	LDPE	1 [b]	Direct Heat	10.47 [a]	0	0.271
						Steam	3.38 [a]	0	
						Electricity	0.47 [a]	0	
High performance LDPE manufacturing device	1 t	40000	30	LDPE	1 [b]	Direct Heat	6.6 [a]	0	0.171
						Steam	2.13 [a]	0	
						Electricity	0.3 [a]	0	

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=t/year/d.u., d.u.=device unit

Table I.1. Characteristics of technologies in industrial sector (continued)

Energy Device	Device Unit	Fixed Cost (JPY)	Life (Years)	Specific Service		Specific Energy Input		Material Use	NOx (kg/yr. /d.u.)
Conventional PP manufacturing device	1 t	44000	30	Polypropylene	1 [b]	Direct Heat	5.21 [a]	0	0.132
						Steam	10.79 [a]	0	
						Electricity	0.13 [a]	0	
High performance PP manufacturing device	1 t	55000	30	Polypropylene	1 [b]	Direct Heat	1.72 [a]	0	0.044
						Steam	3.56 [a]	0	
						Electricity	0.04 [a]	0	
HDPE manufacturing device	1 t	-	1	HDPE	1 [b]	Direct Heat	4.77 [a]	0	0.119
						Steam	4.77 [a]	0	
						Electricity	0.04 [a]	0	
Poly stylen manufacturing device	1 t	-	1	Polystylene	1 [b]	Direct Heat	1.9 [a]	0	0.072
						Steam	1.69 [a]	0	
						Electricity	1.01 [a]	0	
Other petro-chemistry products	1 t	-	1	Other petrochemical	1 [b]	Direct Heat	10.47 [a]	0	1.375
						Steam	39.62 [a]	0	
						Electricity	45.07 [a]	0	
Conventional industrial furnace	100Mcal	5000	30	Electricity	1 [a]	Utility	1 [a]	0	0.025
High performance industrial furnace	100Mcal	5000	30	Electricity	1 [a]	Utility	0.7 [a]	0	0.017
Without O2 control system	100Mcal	-	30	Utility (O2 ctrl.)	1.18 [a]	Utility	1.18 [a]	0	0.000
With O2 control system	100Mcal	104	30	Utility (O2 ctrl.)	1.18 [a]	Utility	1.11 [a]	0	0.000
Conventional boiler	100Mcal	1036	30	Steam from fossil	1 [a]	Utility (O2 ctrl.)	1.18 [a]	0	0.025
Regene boiler	100Mcal	1243	30	Steam from fossil	1 [a]	Utility (O2 ctrl.)	1.11 [a]	0	0.023
Steam of fossil fuel	100Mcal	-	1	Steam	1 [a]	Steam from fossil	1 [a]	0	0.000
Recovery steam	100Mcal	-	1	Steam	1 [a]	Recovered steam	1 [a]	0	0.000
Purchased Electricity	100Mcal	-	1	Direct Heat	1 [a]	Electricity	1 [a]	0	0.000
Industrial-Owned power gnr.	100Mcal	-	1	Direct Heat	1 [a]	Endogenous Ele.	1 [a]	0	0.000
Cnv. Industrial-owned power gnr.	100Mcal	1615	30	Endogenous Ele.	1 [a]	Utility	3.23 [a]	0	0.088
Repowering	100Mcal	1723	30	Endogenous Ele.	1 [a]	Utility	2.56 [a]	0	0.070
Conbined cycle generation	100Mcal	2019	30	Endogenous Ele.	1 [a]	Utility	2 [a]	0	0.055
Recovery	100Mcal	-	30	Endogenous Ele.	1 [a]	Recovered electricity	1 [a]	0	0.000
Phitovlotanic	100Mcal	92180	30	Endogenous Ele.	1 [a]	Solar	2.67 [a]	0	0.000
Coal	100Mcal	-	1	Utility	1 [a]	Coal	1 [a]	0	0.000
Oil	100Mcal	-	1	Utility	1 [a]	Oil Products	1 [a]	0	0.000
Gas	100Mcal	-	1	Utility	1 [a]	Town Gas	1 [a]	0	0.000
Subproduct Gas	100Mcal	-	1	Utility	1 [a]	Subproduct Gas	1 [a]	0	0.000
Staticstical Errors	1 t	-	1	Driving force for adjust	1 [b]	Direct Heat	1 [a]	0	0.000
Industrial Sector - Paper									
Mechanical pulp manufacturing device	1 t	-	30	Mechanical pulp	1 [b]	Chips	2.19 [b]	1	0.000
						Steam	0.62 [a]	0	
						Electricity	14.46 [a]	0	
Waste pulp manufacturing device	1 t	-	30	Waste paper pulp	1 [b]	Chips	1.05 [b]	1	0.000
						Steam	0.75 [a]	0	
						Electricity	2.39 [a]	0	
Semi chemical pulp manufacturing device	1 t	-	30	Semi chemical pulp	1 [b]	Chips	2.83 [b]	1	0.000
						Steam	13.35 [a]	0	
						Electricity	6.75 [a]	0	
Conventional caustification	1 t	3000	30	Cooking liquid	1 [b]	Chemicals	1 [b]	1	0.000
						Oil Products	0.49 [a]	0	
Direct caustification	1 t	3000	30	Cooking liquid	1 [b]	Chemicals	1 [b]	1	0.000
						Oil Products	0 [a]	0	
Conventional cooking device	1 t	15238	30	Non-washed pulp	1 [b]	Chips	3.64 [b]	1	0.000
						Cooking liquid	1 [b]	0	
						Steam	8.56 [a]	0	
Pre-filtration continuos cooking device	1 t	18286	30	Non-washed pulp	1 [b]	Chips	3.64 [b]	1	0.000
						Cooking liquid	1 [b]	0	
						Steam	4.54 [a]	0	
Conventional pulp washing device	1 t	2619	30	Non-dehyd. pulp 1	1 [b]	Non-washed pulp	1 [b]	1	0.000
				Black liquid	1 [b]	Electricity	0.31 [a]	0	
						Non-washed pulp	1 [b]	0	
High performance pulp washing device	1 t	3143	30	Non-dehyd. pulp 1	1 [b]	Non-washed pulp	1 [b]	1	0.000
				Black liquid	1 [b]	Electricity	0.04 [a]	0	
						Non-washed pulp	1 [b]	0	
Selection process	1 t	-	30	Non-dehyd. pulp 2	1 [b]	Non-dehyd. pulp 1	1 [b]	1	0.000
						Electricity	1.16 [a]	0	
Conventional vapor drum	1 t	4464	30	Concentrated black liquid	63.9 [a]	Black liquid	1 [b]	1	0.000
						Steam	11.02 [a]	0	
						Electricity	0.74 [a]	0	

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=t/year/d.u., d.u.=device unit

Table I.1. Characteristics of technologies in industrial sector (continued)

Energy Device	Device Unit	Fixed Cost (JPY)	Life (Years)	Specific Service		Specific Energy Input		Material Use	NOx (kg/yr. /d.u.)
High performance vapor drum	1 t	5357	30	Concentrated black liquid	63.9 [a]	Black liquid	1 [b]	1	0.000
						Steam	9.19 [a]	0	
						Electricity	0.74 [a]	0	
Bleaching process	1 t	-	30	Non-bleached pulp 1	1 [b]	Non-dehyd. pulp 2	1 [b]	1	0.000
						Electricity	0.52 [a]	0	
Conventional delignification device	1 t	3472	30	Non-bleached pulp 2	1 [b]	Non-bleached pulp 1	1 [b]	1	0.000
						Electricity	0.3 [a]	0	
						Oil Products	0.16 [a]	0	
Oxygen delignification device	1 t	4167	30	Non-bleached pulp 2	1 [b]	Non-bleached pulp 1	1 [b]	1	0.000
						Electricity	0.22 [a]	0	
						Oil Products	0.13 [a]	0	
Drum bleaching device	1 t	17593	30	Bleached pulp	1 [b]	Non-bleached pulp 2	1 [b]	1	0.000
						Electricity	0.52 [a]	0	
						Steam	1.92 [a]	0	
Defuser bleaching device	1 t	21111	30	Bleached pulp	1 [b]	Non-bleached pulp 2	1 [b]	1	0.000
						Electricity	0.34 [a]	0	
						Steam	0 [a]	0	
Flow Control (Bleaching)	1 t	-	1	Kraft pulp	1 [b]	Bleached pulp	1 [b]	1	0.000
Flow Control (Non Bleaching)	1 t	-	1	Kraft pulp	1 [b]	Non-dehyd. pulp 2	1 [b]	1	0.000
Flow Control (Mechanical pulp)	1 t	-	1	Pulp	1 [b]	Mechanical pulp	1 [b]	1	0.000
Flow Control (Waste)	1 t	-	1	Pulp	1 [b]	Waste paper pulp	1 [b]	1	0.000
Flow Control (Semi chm. pulp)	1 t	-	1	Pulp	1 [b]	Semi chemical pulp	1 [b]	1	0.000
Flow Control (Kraft pulp)	1 t	-	1	Pulp	1 [b]	Kraft pulp	1 [b]	1	0.000
Flow Control (Import pulp)	1 t	-	1	Pulp	1 [b]	Import pulp	1 [b]	1	0.000
Conventional paper making	1 t	5000	30	Web1	1 [b]	Pulp	1 [b]	1	0.000
						Electricity	4.18 [a]	0	
High density paper making	1 t	5000	30	Web1	1 [b]	Pulp	1 [b]	1	0.000
						Electricity	2.87 [a]	0	
Conventional bearing dehydration device	1 t	2439	30	Web2	1 [b]	Web1	1 [b]	1	0.000
						Steam	14.79 [a]	0	
High performance bearing dehydration device	1 t	2927	30	Web2	1 [b]	Web1	1 [b]	1	0.000
						Steam	9.68 [a]	0	
Conventional dryer hood device	1 t	1543	30	Dry Web	1 [b]	Web2	1 [b]	1	0.000
						Electricity	0.78 [a]	0	
High performance dryer hood device	1 t	1852	30	Dry Web	1 [b]	Web2	1 [b]	1	0.000
						Electricity	0.46 [a]	0	
Press drying, Impulse drying	1 t	4779	30	Dry Web	1 [b]	Web1	1 [b]	1	0.000
						Electricity	0.46 [a]	0	
						Steam	5.68 [a]	0	
Conventional size press device	1 t	4630	30	Forced Web	1 [b]	Dry Web	1 [b]	1	0.000
						Steam	6.24 [a]	0	
High performance size press device	1 t	5556	30	Forced Web	1 [b]	Dry Web	1 [b]	1	0.000
						Steam	0.91 [a]	0	
Flow Control	1 t	-	1	Paper & Board	1 [b]	Forced Web	0.53 [b]	1	0.000
						Dry Web	0.47 [b]	0	
Purchased Electricity	100Mcal	-	1	Electricity	1 [a]	Electricity	1 [a]	0	0.000
Industrial-owned power gnr.	100Mcal	-	1	Electricity	1 [a]	Exogeneous Elec.	1 [a]	0	0.000
Cnv. Industrial-owned power gnr.	100Mcal	1615	30	Exogeneous Elec.	1 [a]	Utility	3.23 [a]	0	0.088
Cnv. Ind.-owned + Repowering	100Mcal	1723	30	Exogeneous Elec.	1 [a]	Utility	2.56 [a]	0	0.070
Conbined cycle generation	100Mcal	2019	30	Exogeneous Elec.	1 [a]	Utility	2 [a]	0	0.055
Phitovlotanic	100Mcal	92180	30	Exogeneous Elec.	1 [a]	Solar	2.62 [a]	0	0.000
Without O2 control system	100Mcal	-	30	Utility (O2 ctrl.)	1.18 [a]	Utility	1.18 [a]	0	0.000
With O2 control system	100Mcal	104	30	Utility (O2 ctrl.)	1.18 [a]	Utility	1.11 [a]	0	0.000
Conventional boiler	100Mcal	1036	30	Steam (Fossil fuel)	1 [a]	Utility (O2 ctrl.)	1.18 [a]	0	0.025
Regene boiler	100Mcal	1243	30	Steam (Fossil fuel)	1 [a]	Utility (O2 ctrl.)	1.11 [a]	0	0.023
Conventional black liquid boiler	100Mcal	500	30	Steam (Black liquid)	0.5 [a]	Concentrated black liquid	1 [b]	0	0.000
High eff. black liquid boiler	100Mcal	500	30	Steam (Black liquid)	0.7 [a]	Concentrated black liquid	1 [b]	0	0.000
Coal	100Mcal	-	30	Utility	1 [a]	Coal	1 [a]	0	0.000
OPR	100Mcal	-	30	Utility	1 [a]	Oil Products	1 [a]	0	0.000
Gas	100Mcal	-	30	Utility	1 [a]	Town Gas	1 [a]	0	0.000
Steam (Fossil fuel)	100Mcal	-	1	Steam	1 [a]	Steam (Fossil fuel)	1 [a]	0	0.000
Steam (Black liquid)	100Mcal	-	1	Steam	1 [a]	Steam (Black liquid)	1 [a]	0	0.000
Other	100Mcal	-	1	Paper & Board	1 [b]	Electricity	1 [a]	0	0.000

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=t/year/d.u., d.u.=device unit

Table I.1. Characteristics of technologies in industrial sector (continued)

Energy Device	Device Unit	Fixed Cost (JPY)	Life (Years)	Specific Service		Specific Energy Input		Material Use	NOx (kg/yr./d.u.)
Industrial Sector - Others									
Energy / Add value	1Myen	-	1	Value added	1 [c]	Energy use	137.2 [a]	1	0.000
Vapor	100Mcal	-	1	Energy use	1 [a]	Steam heat use	1 [a]	0	0.000
Direct Heat	100Mcal	-	1	Energy use	1 [a]	Direct heat use	1 [a]	0	0.000
Other heat	100Mcal	-	1	Energy use	1 [a]	Other heat use	1 [a]	0	0.000
Electricity for power	100Mcal	-	1	Energy use	1 [a]	Ele. use for motor	1 [a]	0	0.000
Other electricity	100Mcal	-	1	Energy use	1 [a]	Other electricity use	1 [a]	0	0.000
Without O2 control system	100Mcal	-	1	Utility (O2 Ctrl.)	1.18 [a]	Fuel for heat	1.18 [a]	0	0.000
With O2 control system	100Mcal	104	30	Utility (O2 Ctrl.)	1.18 [a]	Fuel for heat	1.11 [a]	0	0.000
Conventional boiler	100Mcal	1036	30	Steam heat use	1 [a]	Utility (O2 ctrl.)	1.18 [a]	0	0.025
Regene boiler	100Mcal	1243	30	Steam heat use	1 [a]	Utility (O2 ctrl.)	1.11 [a]	0	0.023
Conventional industrial furnace	100Mcal	5000	30	Direct heat use	1 [a]	Fuel for heat	1 [a]	0	0.028
High performance industrial furnace	100Mcal	5500	30	Direct heat use	1 [a]	Fuel for heat	0.7 [a]	0	0.020
Other Heat	100Mcal	-	1	Other heat use	1 [a]	Fuel for heat	1 [a]	0	0.000
Without inverter	100Mcal	-	1	Controled electricity	1 [a]	Value added	1 [a]	0	0.000
Inverter	100Mcal	1646	30	Controled electricity	1 [a]	Value added	0.65 [a]	0	0.000
Conventinal motor	100Mcal	1651	30	Ele. use for motor	1 [a]	Ctrl. electricity	1 [a]	0	0.000
High performance motor	100Mcal	2229	30	Ele. use for motor	1 [a]	Ctrl. electricity	0.97 [a]	0	0.000
Other electricity	100Mcal	-	1	Other electricity use	1 [a]	Value added	1 [a]	0	0.000
Industrial-owned power geration	100Mcal	-	1	Value added	1 [a]	Endgenous ele.	1 [a]	0	0.000
Purchased Electricity	100Mcal	-	1	Value added	1 [a]	Electricity	1 [a]	0	0.000
Cnv. Industrial-owned power gnr.	100Mcal	1615	30	Endgenous ele.	1 [a]	Fuel for Electricity	3.23 [a]	0	0.088
Cnv. Ind.-owned + Repowering	100Mcal	1723	30	Endgenous ele.	1 [a]	Fuel for Electricity	2.56 [a]	0	0.070
Conbined cycle generation	100Mcal	2019	30	Endgenous ele.	1 [a]	Fuel for Electricity	2 [a]	0	0.055
Water power	100Mcal	-	30	Endgenous ele.	1 [a]	Hydro power	2.616 [a]	0	0.000
Photovlotanic	100Mcal	92180	30	Endgenous ele.	1 [a]	Solar	2.616 [a]	0	0.000
Coal fuel for heat	100Mcal	-	1	Fuel for heat	1 [a]	Coal	1 [a]	0	0.000
Oil fuel for heat	100Mcal	-	1	Fuel for heat	1 [a]	Oil Products	1 [a]	0	0.000
Gas fuel for heat	100Mcal	-	1	Fuel for heat	1 [a]	Town Gas	1 [a]	0	0.000
New energy for heat	100Mcal	-	1	Fuel for heat	1 [a]	New Energy	1 [a]	0	0.000
Coal fuel for electricity	100Mcal	-	1	Fuel for electricity	1 [a]	Coal	1 [a]	0	0.000
Oil fuel for electricity	100Mcal	-	1	Fuel for electricity	1 [a]	Oil Products	1 [a]	0	0.000
Gas fuel for electricity	100Mcal	-	1	Fuel for electricity	1 [a]	Town Gas	1 [a]	0	0.000
New energy for electricity	100Mcal	-	1	Fuel for electricity	1 [a]	New Eenergy	1 [a]	0	0.000

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=t/year/d.u., d.u.=device unit

Table I.2. Characteristics of technologies in residential and commercial sectors

Energy Device	Device Unit	Fixed Cost (10^3JPY)	Life (Years)	Specific Service		Specific Energy Input (10^8cal/yr./d.u.)		Material Use	NOx (kg/yr. /d.u.)
Residential Sector									
Conventional air conditioner (cool)	1 unit	171	10	Cooling	13.26 [a]	Electricity	4.74	0	0.00
High efficiency air conditioner, Top Runner Standard (cool)	1 unit	180	10	Cooling	13.26 [a]	Electricity	4.74	0	0.00
High efficiency air conditioner, 2000's highest (cool)	1 unit	216	10	Cooling	13.26 [a]	Electricity	2.41	0	0.00
Conventional air conditioner (cool&warm)	1 unit	190	10	Warming	38.75 [a]	Electricity	17.18	0	0.00
				Cooling	13.26 [a]				
High efficiency air conditioner, Top Runner Standard	1 unit	200	10	Warming	38.75 [a]	Electricity	17.18	0	0.00
				Cooling	13.26 [a]				
High efficiency air conditioner, 2000's highest (cool&warm)	1 unit	240	10	Warming	38.75 [a]	Electricity	8.92	0	0.00
				Cooling	13.26 [a]				
Oil stove	1 unit	3	8	Warming	23.60 [a]	Kerosene	25.49	0	0.07
Oil fan heater	1 unit	20	8	Warming	34.33 [a]	Kerosene	37.05	0	0.63
						Electricity	1.58	0	
Forced draft balanced oil fan heater	1 unit	118	8	Warming	34.97 [a]	Kerosene	40.58	0	0.62
Gas fan heater	1 unit	50	8	Warming	21.46 [a]	Town Gas	21.46	0	0.15
Forced draft balanced gas heater	1 unit	133	8	Warming	42.91 [a]	Town Gas	51.49	0	0.75
Gas fan heater	1 unit	50	8	Warming	21.46 [a]	LPG	21.46	0	0.18
Forced draft balanced gas heater	1 unit	133	8	Warming	42.91 [a]	LPG	51.49	0	0.85
Oil water heater	1 unit	244	15	Hot water (t.g. area)	25.28 [a]	Kerosene	38.90	0	0.97
Gas water heater	1 unit	156	15	Hot water (t.g. area)	25.28 [a]	Town Gas	33.71	0	0.63
Electric water heater	1 unit	240	15	Hot water (t.g. area)	25.28 [a]	Electricity	28.09	0	0.00
Solar thermal water heater	1 unit	190	10	Hot water (t.g. area)	12.50 [a]	Solar Heat	12.50	0	0.00
Solar system with heat exchange media	1 unit	550	33	Hot water (t.g. area)	19.50 [a]	Solar Heat	19.50	0	0.00
Latent heat recovery type	1 unit	190	15	Hot water (t.g. area)	25.28 [a]	Town Gas	26.61	0	0.50
Water heater with CO2 refrigerant	1 unit	400	15	Hot water (t.g. area)	25.28 [a]	Electricity	8.43	0	0.16
Fuel cell for household	1 unit	500	20	Hot water (t.g. area)	26.73 [a]	Town Gas	66.83	0	0.00
				Electricity	23.39 [a]				
Oil water heater	1 unit	244	15	Hot water (LPG area)	25.28 [a]	Kerosene	38.90	0	0.97
Gas water heater	1 unit	156	15	Hot water (LPG area)	25.28 [a]	LPG	33.71	0	0.72
Electric water heater	1 unit	240	15	Hot water (LPG area)	25.28 [a]	Electricity	28.09	0	0.00
Solar thermal water heater	1 unit	190	10	Hot water (LPG area)	12.50 [a]	Solar Heat	12.50	0	0.00
Solar system with heat exchange media	1 unit	550	33	Hot water (LPG area)	19.50 [a]	Solar Heat	19.50	0	0.00
Latent heat recovery type	1 unit	190	15	Hot water (LPG area)	25.28 [a]	LPG	26.61	0	0.57
Water heater with CO2 refrigerant	1 unit	400	15	Hot water (LPG area)	25.28 [a]	Electricity	8.43	0	0.18
Fuel cell for household	1 unit	500	20	Hot water (LPG area)	26.73 [a]	LPG	66.83	0	0.00
				Electricity	23.39 [a]				
Incandescent	1 unit	0.2	1	Light (Incandescent)	0.50 [a]	Electricity	0.50	0	0.00
Fluorescent of incandescent type	1 unit	2.1	6	Light (Incandescent)	0.50 [a]	Electricity	0.17	0	0.00
Conventional fluorescent	1 unit	14	7	Light (Fluorescent)	0.19 [a]	Electricity	0.19	0	0.00
Fluorescent with enery saving stabilizer	1 unit	18	7	Light (Fluorescent)	0.19 [a]	Electricity	0.17	0	0.00
Inverter type fluorescent	1 unit	18	7	Light (Fluorescent)	0.19 [a]	Electricity	0.16	0	0.00
Hf Inverter type fluorescent	1 unit	23	7	Light (Fluorescent)	0.19 [a]	Electricity	0.14	0	0.00
Conventional refrigerator	1 unit	170	6	Refrigerator	1.00 [b]	Electricity	7.24	0	0.00
High efficiency refrigerator, Top Runner Standard	1 unit	180	6	Refrigerator	1.00 [b]	Electricity	7.24	0	0.00
High efficiency refrigerator, 2000's highest	1 unit	183	6	Refrigerator	1.00 [b]	Electricity	3.51	0	0.00
Kotatsu	1 unit	10	6	Kotatsu	1.00 [b]	Electricity	1.63	0	0.00
Fan	1 unit	10	6	Fan	1.00 [b]	Electricity	0.15	0	0.00
Electric blanket	1 unit	10	6	Electric blanket	1.00 [b]	Electricity	0.48	0	0.00
Electric fan heater	1 unit	10	6	Electric fan heater	1.00 [b]	Electricity	0.83	0	0.00
Washing machine	1 unit	10	6	Washing machine	1.00 [b]	Electricity	0.47	0	0.00
Vacuum cleaner	1 unit	10	6	Vacuum cleaner	1.00 [b]	Electricity	1.14	0	0.00
Microwave oven	1 unit	10	6	Microwave oven	1.00 [b]	Electricity	1.03	0	0.00
Clothing drier	1 unit	10	6	Clothing drier	1.00 [b]	Electricity	4.44	0	0.00
Electric carpet	1 unit	10	6	Electric carpet	1.00 [b]	Electricity	2.63	0	0.00

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=number of device unit/year/d.u., d.u.=device unit

Table I.2. Characteristics of technologies in residential and commercial sectors (continued)

Energy Device	Device Unit	Fixed Cost (10^3JPY)	Life (Years)	Specific Service		Specific Energy Input (10^8cal/yr./d.u.)		Material Use	NOx (kg/yr. /d.u.)
Conventional TV	1 unit	50	6	Television	1.00 [b]	Electricity	2.20	0	0.00
High efficiency TV, Top Runner Standard	1 unit	51	6	Television	1.00 [b]	Electricity	2.20	0	0.00
High efficiency TV, 2000's highest	1 unit	52	6	Television	1.00 [b]	Electricity	1.44	0	0.00
Liquid crystal display TV	1 unit	100	6	Television	1.00 [b]	Electricity	0.92	0	0.00
Conventional VTR	1 unit	20	6	VTR	1.00 [b]	Electricity	0.60	0	0.00
High efficiency VTR, Top Runner Standard	1 unit	21	6	VTR	1.00 [b]	Electricity	0.60	0	0.00
2000's highest efficiency VTR	1 unit	21	6	VTR	1.00 [b]	Electricity	0.09	0	0.00
Conventional stereo	1 unit	50	6	Stereo	1.00 [b]	Electricity	0.85	0	0.00
High efficiency stereo	1 unit	52	6	Stereo	1.00 [b]	Electricity	0.25	0	0.00
Conventional combination tape recorder and radio	1 unit	20	6	Compact Stereo	1.00 [b]	Electricity	0.30	0	0.00
High efficiency combination tape recorder and radio	1 unit	21	6	Compact Stereo	1.00 [b]	Electricity	0.17	0	0.00
Conventional combination tape recorder and radio	1 unit	20	6	Compact Stereo	1.00 [b]	Electricity	0.30	0	0.00
High efficiency combination tape recorder and radio	1 unit	21	6	Compact Stereo	1.00 [b]	Electricity	0.17	0	0.00
Desktop personal computer (CRT)	1 unit	200	5	Desktop type PC	1.00 [b]	Electricity	0.75	0	0.00
Desktop personal computer (LCD)	1 unit	250	5	Desktop type PC	1.00 [b]	Electricity	0.40	0	0.00
Note type personal computer	1 unit	10	5	Note type PC	1.00 [b]	Electricity	0.08	0	0.00
Word processor	1 unit	10	5	Word processor	1.00 [b]	Electricity	0.04	0	0.00
Toilet bow with a warm water cleaner	1 unit	10	6	Toilet bow with a warm water cleaner	1.00 [b]	Electricity	0.21	0	0.00
Other electricity use	1 unit	50	6	Other electricity use	1.00 [b]	Electricity	4.36	0	0.00
Other ele. use (standby power saving; 5%)	1 unit	51	6	Other electricity use	1.00 [b]	Electricity	4.25	0	0.00
Other ele. use (standby power saving; 10%)	1 unit	52	6	Other electricity use	1.00 [b]	Electricity	4.13	0	0.00
Other ele. use (standby power saving; 20%)	1 unit	53	6	Other electricity use	1.00 [b]	Electricity	3.90	0	0.00
Photovoltaic power generation	1 unit	3,000	20	Electricity	31.54 [a]	Solar Power	70.96	0	0.00
Flow control	1 unit	0	1	Electricity	1.00	Electricity	1.00	0	0.00
Commercial Sector									
Gas engine co-generation	1kW	200	30	Warming	8.45 [a]	Town Gas	58	0	177.4
				Cooling	8.45 [a]				
				Hot water (t.g. area)	11.27 [a]				
				Electricity	14.53 [a]				
Gas turbine co-generation	1kW	220	30	Warming	14.84 [a]	Town Gas	104	0	17.7
				Cooling	14.84 [a]				
				Hot water (t.g. area)	19.79 [a]				
				Electricity	22.16 [a]				
Oil turbine co-generatioin	1kW	220	30	Warming	14.84 [a]	Heavy Oil	104	0	29.9
				Cooling	14.84 [a]				
				Hot water (LPG area)	19.79 [a]				
				Electricity	22.16 [a]				
Oil engine co-generation	1kW	200	30	Warming	7.47 [a]	Heavy Oil	78	0	302.1
				Cooling	7.47 [a]				
				Hot water (LPG area)	9.97 [a]				
				Electricity	27.10 [a]				
Fuel cell co-generation (t.g. area)	1kW	450	30	Warming	14.91 [a]	Town Gas	124	0	0.0
				Cooling	14.91 [a]				
				Hot water (t.g. area)	19.88 [a]				
				Electricity	49.71 [a]				
Fuel cell co-generation (LPG area)	1kW	450	30	Warming	14.91 [a]	LPG	124	0	0.0
				Cooling	14.91 [a]				
				Hot water (LPG area)	19.88 [a]				
				Electricity	49.71 [a]				
Conventional air conditioner (cool)	1 unit	1,800	20	Cooling	173 [a]	Electricity	69	0	0.00
High efficiency air conditioner, Top Runner Standard (cool)	1 unit	1,800	20	Cooling	173 [a]	Electricity	69	0	0.00
High efficiency air conditioner, 2000's highest (cool)	1 unit	1,900	20	Cooling	173 [a]	Electricity	43	0	0.00

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=number of device unit/year/d.u., d.u.=device unit

Table I.2. Characteristics of technologies in residential and commercial sectors (continued)

Energy Device	Device Unit	Fixed Cost (10^3JPY)	Life (Years)	Specific Service		Specific Energy Input (10^8cal/yr./d.u.)		Material Use	NOx (kg/yr. /d.u.)
Conventional air conditioner (cool&warm)	1 unit	1,850	20	Warming	311 [a]	Electricity	180	0	0.00
				Cooling	173 [a]				
High efficiency air conditioner, Top Runner Standard	1 unit	1,850	20	Warming	311 [a]	Electricity	180	0	0.00
				Cooling	173 [a]				
High efficiency air conditioner, 2000's highest (cool&warm)	1 unit	2,280	20	Warming	311 [a]	Electricity	112	0	0.00
				Cooling	173 [a]				
Gas heat pump	1 unit	1,900	20	Warming	311 [a]	Town Gas	336	0	86.8
				Cooling	173 [a]	Electricity	10	0	
Oil heat pump	1 unit	2,200	20	Warming	311 [a]	Kerosene	336	0	90.0
				Cooling	173 [a]	Electricity	10	0	
Gas absorption heat pump	1 unit	58,100	30	Warming	12100 [a]	Town Gas	29,740	0	14.7
				Cooling	16300 [a]	Electricity	135	0	
Oil absorption heat pump	1 unit	60,000	30	Warming	12100 [a]	Heavy Oil	29,740	0	21.9
			30	Cooling	16300 [a]	Electricity	232	0	
Reduction of heat source burden	$1000m^2$	3,100	20	Warming	240.2 [a]	New Energy	0	0	0.0
			20	Cooling	31.2 [a]				
Oil heat boiler (heavy oil)	1 unit	1,186	20	Warming	240 [a]	Heavy Oil	304	0	24.0
Oil heat boiler (kerosene)	1 unit	1,186	20	Warming	240 [a]	Kerosene	304	0	20.3
Gas heat boiler (town gas)	1 unit	1,186	20	Warming	240 [a]	Town Gas	278	0	18.3
Gas heat boiler (LPG)	1 unit	1,186	20	Warming	240 [a]	LPG	278	0	24.3
Coal heat boiler	1 unit	1,186	20	Warming	240 [a]	Coke	304	0	70.5
Oil hot water boiler (heavy oil)	1 unit	1,186	20	Hot water (t.g. area)	240 [a]	Heavy Oil	304	0	21.4
Oil hot water boiler (kerosene)	1 unit	1,186	20	Hot water (t.g. area)	240 [a]	Kerosene	304	0	18.4
Gas hot water boiler (town gas)	1 unit	1,186	20	Hot water (t.g. area)	240 [a]	Town Gas	278	0	15.2
Coal hot water boiler	1 unit	1,186	20	Hot water (t.g. area)	240 [a]	Coke	304	0	27.9
Latent heat recovery type boiler	1 unit	1,245	20	Hot water (t.g. area)	240 [a]	Town Gas	253	0	15.2
Solar water heater	1 unit	1,010	20	Hot water (t.g. area)	30.6 [a]	Solar Heat	31	0	0.0
Waste heat recovery type boiler	1 unit	1,186	20	Hot water (t.g. area)	240 [a]	New Energy	304	0	0.0
Oil hot water boiler (heavy oil)	1 unit	1,186	20	Hot water (LPG area)	240 [a]	Heavy Oil	304	0	21.4
Oil hot water boiler (kerosene)	1 unit	1,186	20	Hot water (LPG area)	240 [a]	Kerosene	304	0	18.4
Gas hot water boiler (LPG)	1 unit	1,186	20	Hot water (LPG area)	240 [a]	LPG	278	0	22.8
Coal hot water boiler	1 unit	1,186	20	Hot water (LPG area)	240 [a]	Coke	304	0	27.9
Latent heat recovery type boiler	1 unit	1,305	20	Hot water (LPG area)	240 [a]	LPG	253	0	22.8
Waste heat recovery type boiler	1 unit	1,010	20	Hot water (LPG area)	30.6 [a]	Solar Heat	31	0	0
Gas cooker	$100m^2$	100	6	Cooking	1 [a]	Town Gas	17	0	28.78
Coal cooker	$100m^2$	100	6	Cooking	1 [a]	Coke	17	0	52.67
Gas cooker	$100m^2$	100	6	Cooking	1 [a]	LPG	17	0	29.93
Conventional fluorescent	$100m^2$	484	11	Light (fluorescent)	1 [a]	Electricity	51	0	0
Lighting with high frequency inverter	$100m^2$	484	11	Light (fluorescent)	1 [a]	Electricity	41	0	0
Light. with high frq. Inv. (ill. cntl.)	$100m^2$	553	11	Light (fluorescent)	1 [a]	Electricity	26	0	0
Light. with high frq. Inv. (tim. cntl.)	$100m^2$	671	11	Light (fluorescent)	1 [a]	Electricity	22	0	0
Incandescent	$100m^2$	40	1	Light (incandescent)	1 [a]	Electricity	51	0	0
Fluorescent of incandescent type	$100m^2$	250	7	Light (incandescent)	1 [a]	Electricity	17	0	0
Conventional fire-exit light	$100m^2$	39	10	Fire exit light	1 [a]	Electricity	2	0	0
Extra bright fire exit light	$100m^2$	41	10	Fire exit light	1 [a]	Electricity	1	0	0
Mainframe	$100m^2$	610	6	Mainframe	1 [a]	Electricity	2	0	0
Energy saving type Mainframe	$100m^2$	611	6	Mainframe	1 [a]	Electricity	2	0	0
Conventional duplicator	$100m^2$	30	6	Duplicator	1 [a]	Electricity	2	0	0
High eff. dupl., Top Runner standard	$100m^2$	30	6	Duplicator	1 [a]	Electricity	2	0	0
2000's highest efficiency duplicator	$100m^2$	33	6	Duplicator	1 [a]	Electricity	2	0	0
Elevator	$100m^2$	690	17	Elevator	1 [a]	Electricity	2	0	0
FAX	$100m^2$	10	6	FAX	1 [a]	Electricity	0	0	0
Personal computer	$100m^2$	20	6	Personal Computer	1 [a]	Electricity	1	0	0
Energy saving type PC	$100m^2$	22	6	Personal Computer	1 [a]	Electricity	0	0	0
Pumping power for air conditioner	$100m^2$	100	6	Pumping power for air conditioner	1 [a]	Electricity	11	0	0
Pumping power (VAV control)	$100m^2$	119	6	Pumping power for air conditioner	1 [a]	Electricity	8	0	0
Pumping power (VAV + low pressure loss)	$100m^2$	135	6	Pumping power for air conditioner	1 [a]	Electricity	6	0	0

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=number of device unit/year/d.u., d.u.=device unit

Table I.2. Characteristics of technologies in residential and commercial sectors (continued)

Energy Device	Device Unit	Fixed Cost (10^3JPY)	Life (Years)	Specific Service		Specific Energy Input (10^8cal/yr./d.u.)		Material Use	NOx (kg/yr. /d.u.)
Other electricity use	100m^2	100		Others	1 [a]	Electricity	21	0	
Other ele. use (standby power saving; 5%)	100m^2	106		Others	1 [a]	Electricity	20	0	0
Other ele. use (standby power saving; 10%)	100m^2	115	6	Others	1 [a]	Electricity	19	0	0
Other ele. use (standby power saving; 20%)	100m^2	123	6	Others	1 [a]	Electricity	17	0	0
Photovoltaic power generation	1kW	1,700	6	Electricity	10.512 [a]	Solar Power	24	0	0
Flow control	1	-	6	Electricity	1 [a]	Electricity	1	0	0

Note: Unit with "a"=10^8cal/year/d.u., Unit with "b"=number of device unit/year/d.u., d.u.=device unit

Table I.3. Characteristics of technologies in transportation sector

Energy Device	Device Unit	Fixed Cost (10^3JPY)	Life (Years)	Specific Service (100 person-km/yr/d.u.)		Specific Energy Input (10^8cal/yr./d.u.)		Material Use	NOx (kg/yr. /d.u.)
Passenger Transporation									
Mini car (gasoline)	1 unit	748	10	Mini private car	98	Gasoline	51.3	0	1.01
Mini car (gasoline, high eff.)	1 unit	785	10 0	Mini private car	98	Gasoline	43.0	0	1.01
Mini car (electricity)	1 unit	4,000	10	Mini private car	98	Electricity	11.7	0	
Mini car (gasoline hybrid)	1 unit	5,000	10 0	Mini private car	98	Gasoline	23.6	0	
Mini car (fuel cell, gasoline)	1 unit	5,000	10	Mini private car	98	Gasoline	25.2	0	
Mini car (fuel cell, town gas)	1 unit	5,000	10	Mini private car	98	Town Gas	25.7	0	
Mini car (fuel cell, methane)	1 unit	5,000	10	Mini private car	98	Methanol	24.1	0	
Mini car (fuel cell, hydrogen)	1 unit	5,000	10	Mini private car	98	Hydrogen	21.6	0	
Small car (gasoline)	1 unit	1,527	10	Small private car	152	Gasoline	84.5	0	1.68
Small car (diesel)	1 unit	1,464	10	Small private car	152	Lighting	100.7	0	6.14
Small car (diesel, high eff.)	1 unit	1,537	10	Small private car	152	Lighting	84.1	0	6.14
Small car (gasoline, high eff.)	1 unit	1,603	10	Small private car	152	Gasoline	62.6	0	1.68
Small car (electricity)	1 unit	4,950	10	Small private car	152	Electricity	14.6	0	
Small car (compressed town gas)	1 unit	2,000	10	Small private car	152	Town Gas	83.3	0	
Small car (gasoline hybrid)	1 unit	2,150	10	Small private car	152	Gasoline	42.3	0	
Small car (fuel cell, Hydrogen)	1 unit	5,000	10	Small private car	152	Hydrogen	35.5	0	
Small car (fuel cell, gasoline)	1 unit	5,000	10	Small private car	152	Gasoline	41.4	0	
Small car (fuel cell, town gas)	1 unit	5,000	10	Small private car	152	Town Gas	42.3	0	
Small car (fuel cell, methane)	1 unit	5,000	10	Small private car	152	Methanol	39.7	0	
Standard car (gasoline)	1 unit	3,020	8	Regular private car	152	Gasoline	123.5	0	1.68
Standard car (diesel)	1 unit	2,990	8	Regular private car	152	Lighting	147.1	0	6.14
Standard car (diesel, high eff.)	1 unit	3,140	8	Regular private car	152	Lighting	122.8	0	6.14
Standard vhcl. (gsln. drct. inj.)	1 unit	3,096	8	Regular private car	152	Gasoline	95.0	0	1.68
Standard vhcl. (electricity)	1 unit	9,540	8	Regular private car	152	Electricity	16.7	0	
Standard vhcl. (natural gas)	1 unit	6,415	8	Regular private car	152	Town Gas	128.1	0	
Standard vhcl. (CVT)	1 unit	3,035	8	Regular private car	152	Gasoline	112.2	0	
Standard vhcl. (gasoline hybrid)	1 unit	5,000	8	Regular private car	152	Gasoline	56.8	0	
Standard vhcl. (fuel cell, gsl.)	1 unit	5,000	8	Regular private car	152	Gasoline	60.5	0	
Standard vhcl. (fuel cell, gas)	1 unit	5,000	8	Regular private car	152	Town Gas	61.7	0	
Standard vhcl. (fuel cell, mthn.)	1 unit	5,000	8	Regular private car	152	Methanol	58.0	0	
Standard vhcl. (fuel cell, H2)	1 unit	5,000	8	Regular private car	152	Hydrogen	51.9	0	
Commercial car (LPG)	1 unit	1,780	10	Commercial car	479	LPG	905.4	0	11.06
Commercial car (gasoline)	1 unit	3,020	10	Commercial car	479	Gasoline	603.2	0	11.06
Commercial car (diesel)	1 unit	1,812	10	Commercial car	479	Lighting	448.7	0	40.35
Commercial car (diesel, high eff.)	1 unit	1,903	10	Commercial car	479	Lighting	374.6	0	40.35
Commercial car (gasoline drct. in.)	1 unit	3,096	10	Commercial car	479	Gasoline	464.0	0	11.06
Commercial car (gasoline hybrid)	1 unit	4,252	10	Commercial car	479	Gasoline	277.5	0	
Commercial car (fuel cell, gsln.)	1 unit	5,000	10	Commercial car	479	Gasoline	295.6	0	
Commercial car (fuel cell, gas)	1 unit	5,000	10	Commercial car	479	Town Gas	301.6	0	
Commercial car (fuel cell, mthn.)	1 unit	5,000	10	Commercial car	479	Methanol	283.5	0	
Commercial car (fuel cell, H2)	1 unit	5,000	10	Commercial car	479	Hydrogen	253.4	0	
Private bus (gasoline)	1 unit	2,052	12	Private bus	1403	Gasoline	147.7	0	19.38
Private bus (diesel)	1 unit	4,430	12	Private bus	1403	Lighting	198.5	0	54.11
Private bus (electricity)	1 unit	25,000	12	Private bus	1403	Electricity	63.4	0	
Private bus (CNG)	1 unit	16,660	12	Private bus	1403	Town Gas	538.4	0	
Private bus (gasoline hybrid)	1 unit	14,050	12	Private bus	1403	Gasoline	165.5	0	
Private bus (fuel cell, gasoline)	1 unit		12	Private bus	1403	Gasoline	97.3	0	
Private bus (fuel cell, methane)	1 unit		12	Private bus	1403	Methanol	93.3	0	
Private bus (fuel cell, hydrogen)	1 unit		12	Private bus	1403	Hydrogen	83.4	0	
Commercial bus (diesel)	1 unit	14,100	14	Commercial bus	7381	Lighting	1,266.0	0	177.06
Commercial bus (CNG)	1 unit	22,815	14	Commercial bus	7381	Town Gas	4,742.8	0	
Commercial bus (diesel hybrid)	1 unit	20,000	14	Commercial bus	7381	Lighting	1,055.0	0	
Commercial bus (fuel cell, gsln.)	1 unit		14	Commercial bus	7381	Gasoline	620.3	0	
Commercial bus (fuel cell, mthn.)	1 unit		14	Commercial bus	7381	Methanol	595.0	0	
Commercial bus (fuel cell, H2)	1 unit		14	Commercial bus	7381	Hydrogen	531.7	0	
Private truck (gasoline)			1	Private truck	1	Gasoline	0.4	0	
Private truck (diesel)			1	Private truck	1	Lighting	0.4	0	
Railroad (electricity)			1	Railroad	1	Electricity	0.0	0	
Railroad (diesel)			1	Railroad	1	Lighting	0.0	0	0.015
Ship (diesel)			1	Domestic shipping	1	Heavy Oil	0.4	0	0.286
Ship (hot valve)			1	Domestic shipping	1	Lighting	0.4	0	0.286
Airplane			1	Domestic airline	1	Jet fuel	0.5	0	0.056

d.u.=device unit

Table I.3. Characteristics of technologies in transportation sector (continued)

Energy Device	Device Unit	Fixed Cost (10^3JPY)	Life (Years)	Specific Service (100 ton-km/yr./d.u.)		Specific Energy Input (10^8cal/yr./d.u.)		Material Use	NOx (kg/yr. /d.u.)
Freight Transportaion									
Mini prv. truck (gasoline)	1 unit	953	10	Mini prv. truck	1.5	Gasoline	13.9	0	4.65
Mini prv. truck (gasoline, high eff.)	1 unit	1,001	10	Mini prv. truck	1.5	Gasoline	12.5	0	
Mini prv. truck (electricity)	1 unit	3,100	10	Mini prv. truck	1.5	Electricity	4.9	0	
Mini prv. truck (CNG)	1 unit	1,950	10	Mini prv. truck	1.5	Town Gas	32.4	0	
Mini prv. truck (fuel cell, gasoline)	1 unit	5,000	10	Mini prv. truck	1.5	Gasoline	6.8	0	
Mini prv. truck (fuel cell, methane)	1 unit	5,000	10	Mini prv. truck	1.5	Methanol	6.5	0	
Small prv. truck (gasoline)	1 unit	1,279	10	Small prv. trick	15	Gasoline	103.0	0	7.70
Small prv. truck (gasoline,high eff.)	1 unit	1,343	10	Small prv. trick	15	Gasoline	92.5	0	7.70
Small prv. truck (diesel)	1 unit	1,264	10	Small prv. trick	15	Lighting	131.6	0	12.55
Small prv. truck (diesel,high eff.)	1 unit	1,327	10	Small prv. trick	15	Lighting	121.3	0	12.55
Small prv. truck (electricity)	1 unit	11,230	10	Small prv. trick	15	Electricity	95.2	0	
Small prv. truck (CNG)	1 unit	2,130	10	Small prv. trick	15	Town Gas	316.5	0	
Small prv. truck (fuel cell, gasoline)	1 unit	5,000	10	Small prv. trick	15	Gasoline	64.5	0	
Small prv. truck (fuel cell, methane)	1 unit	5,000	10	Small prv. trick	15	Methanol	61.9	0	
Standard prv. truck (gasoline)	1 unit	1,619	12	Regular prv. truck	277	Gasoline	119.1	0	18.88
Standard prv. truck (diesel)	1 unit	2,924	12	Regular prv. truck	277	Lighting	335.6	0	60.85
Standard prv. truck (electricity)	1 unit	20,000	12	Regular prv. truck	277	Electricity	124.5	0	
Standard prv. truck (CNG)	1 unit	4,755	12	Regular prv. truck	277	Town Gas	1,129.5	0	
Standard prv. truck (diesel hybrid)	1 unit	12,000	12	Regular prv. truck	277	Lighting	335.6	0	
Standard prv. truck (fuel cell, gasoline)	1 unit	99,999	12	Regular prv. truck	277	Gasoline	164.4	0	
Standard prv. truck (fuel cell, methane)	1 unit	99,999	12	Regular prv. truck	277	Methanol	157.7	0	
Mini cmm. truck (gasoline)	1 unit	953	10	Mini cmm. truck	31	Gasoline	211.1	0	16.66
Mini cmm. truck (gasoline, high eff.)	1 unit	1,001	10	Mini cmm. truck	31	Gasoline	189.6	0	16.66
Mini cmm. truck (electricity)	1 unit	3,100	10	Mini cmm. truck	31	Electricity	75.0	0	
Mini cmm. truck (CNG)	1 unit	1,950	10	Mini cmm. truck	31	Town Gas	493.7	0	
Mini cmm. truck (fuel cell, gasoline)	1 unit	5,000	10	Mini cmm. truck	31	Gasoline	103.4	0	
Mini cmm. truck (fuel cell, methane)	1 unit	5,000	10	Mini cmm. truck	31	Methanol	99.2	0	
Small cmm. truck (gasoline)	1 unit	1,533	10	Small cmm. trick	117	Gasoline	229.8	0	14.97
Small cmm. truck (gasoline, high eff.)	1 unit	1,610	10	Small cmm. trick	117	Gasoline	206.4	0	14.97
Small cmm. truck (diesel)	1 unit	1,715	10	Small cmm. trick	117	Lighting	338.7	0	24.40
Small cmm. truck (diesel, high eff.)	1 unit	1,801	10	Small cmm. trick	117	Lighting	312.1	0	24.40
Small cmm. truck (electricity)	1 unit	11,230	10	Small cmm. trick	117	Electricity	244.9	0	
Small cmm. truck (CNG)	1 unit	2,130	10	Small cmm. trick	117	Town Gas	814.3	0	
Small cmm. truck (fuel cell, gasoline)	1 unit	5,000	10	Small cmm. trick	117	Gasoline	166.0	0	
Small cmm. truck (fuel cell, methane)	1 unit	5,000	10	Small cmm. trick	117	Methanol	159.2	0	
Standard cmm. truck (diesel)	1 unit	4,600	12	Standard cmm. truck	2276	Lighting	1,425.5	0	203.80
Standard cmm. truck (CNG)	1 unit	9,333	12	Standard cmm. truck	2276	Town Gas	3,809.8	0	
Standard cmm. truck (diesel hybrid)	1 unit	12,000	12	Standard cmm. truck	2276	Lighting	1,425.5	0	
Standard cmm. truck (fuel cell, gasln.)	1 unit	99,999	12	Standard cmm. truck	2276	Gasoline	698.5	0	
Standard cmm. truck (fuel cell, mthn.)	1 unit	99,999	12	Standard cmm. truck	2276	Methanol	670.0	0	
Railroad (electricity)		9,999	1	Railroad	1	Electricity	0.1	0	
Railroad (diesel)		9,999	1	Railroad	1	Lighting	0.1	0	0.026
Ship (diesel)		9,999	1	Domestic shipping	1	Heavy Oil	0.2	0	0.173
Air plane		9,999	1	Domestic airline	1	Jet fuel	5.5	0	0.663

d.u.=device unit, prv.=private, cmm.=commercial

* Mini vechicle: Overall length 3.4m or less, Overall width 1.48m or less, Overall height 2.0m or less, Displacement 660cc

* Small vechicle: Overall length 4.7m or less, Overall width 1.7m or less, Overall height 2.0m or less, Displacement 2000cc

* Standard vechicle: Larger than small vechicle

Table I.4. Characteristics of technologies in energy conversion sector

Energy Device	Device Unit	Fixed Cost (10^3JPY)	Life (Years)	Specific Service (10^8cal/yr./d.u)		Specific Energy Input (10^8cal/yr./d.u.)		Mate-rial Use	NOx (kg/yr. /d.u.)
Electricity Generation									
Transmission loss	1		1	Electricity sales	1	Ele. Before trasmission	1	0	0.00
Ele. Ex. Pumping-up	1		1 0	Ele. Before trasmissi	1	Ele. Incl. Pumping	1	0	0.00
Pumping-up power plant	1 kW	75.34	40	Ele. Before trasmissi	75.34	Ele. Incl. Pumping	166	0	0.00
Nuclear power plant	1kW	430	40 0	Ele. Incl. Pumping	72.03	Nuclear Power	197	0	0.00
hydro power plant	1kW	882	40	Ele. Incl. Pumping	74.96	Hydro Power	197	0	0.00
Flow control	1		1	Ele. Incl. Pumping	1	Ele. Gerated from fossil fuel	1	0	0.00
Geothermal power plant	1kW		40	Ele. Incl. Pumping	69.31	Geothermal Power	197.1	0	0.00
Waste power plant	1kW		40	Ele. Incl. Pumping	67.81	Waste Power	197.1	0	0.00
Wind power plant	1kW		40	Ele. Incl. Pumping	67.81	Wind Power	197.1	0	0.00
Biomass power plant	1kW		40	Ele. Incl. Pumping	67.81	Biomass Power	197.1	0	0.00
Solar power plant	1kW		40	Ele. Incl. Pumping	75.34	Solar Heat	197.1	0	0.00
Flow control (oil)	1		1	Ele. Gerated from fossil fuel	1	Ele. By oil plant	1	0	0.00
Flow control (coal)	1		1	Ele. Gerated from fossil fuel	1	Ele. By coal plant	1	0	0.00
Flow control (gas)	1		1	Ele. Gerated from fossil fuel	1	Ele. By gas plant	1	0	0.00
Conventional oil plant	1kW	190	40	Ele. By oil plant	71.57	Oil	190.3	0	5.94
Hi performance oil plant	1kW	190	40	Ele. By oil plant	71.57	Oil	178.9	0	5.58
Conventional coal plant	1kW	289	40	Ele. By coal plant	71.57	Coal	180.4	0	12.81
Hi performance coal plant	1kW	289	40	Ele. By coal plant	71.57	Coal	178.9	0	12.70
Conventional gas plant	1kW	208	40	Ele. By gas plant	73.08	Natural Gas	179.4	0	2.69
Hi performance NG plant	1kW	208	40	Ele. By gas plant	73.08	Natural Gas	149.1	0	2.24
Town Gas									
Town gas from coke	1		1	Town Gas Sales	1	Coal Products	1.26	0.797	0.00
						Electricity	0.01	0	
Town gas from LPG	1		1	Town Gas Sales	1	LPG	1.26	0.797	0.00
						Electricity	0.01	0	
Town gas from natural gas	1		1	Town Gas Sales	1	Natural Gas	1.00	0.996	0.00
						Electricity	0.01	0	
Oil Refinery									
Oil refining (conventional)	1		30	Oil Products Sales	1	Oil	1.00	1	0.001
						Electricity	0.00	0	
						Oil Products	0.05	0	
Oil refining (new)	1		30	Oil Products Sales	1	Oil	1.00	1	0.001
						Electricity	0.00	0	
						Oil Products	0.05	0	
Oil refining (advanced)	1		30	Oil Products Sales	1	Oil	1.00	1	0.001
						Electricity	0.00	0	
						Oil Products	0.04	0	

d.u.=device unit

Appendix J: Typical numbers for characteristics of some removal processes

The characteristics of removal process and their estimation method are listed in this Appendix. The value provided here can be used as input data of Removal Process table in AIM/Enduse Database System.

J.1 Removal process for SO_2 emission

J.1.1 Coal washing

Coal washing is the most effective precombustion process to reduce SO_2 emission. It involves physical and chemical cleaning of coal. Table J.1 shows the physical coal cleaning's parameters for produced coal in U.S.A. It is estimated with using the value in Kaplan (1994). The assumption in the estimate is that the cite capacity is 500 t/hour and the capacity utilization is 11 hours/day and 365 days/year. The assumption is following Kaplan (1994). Coal washing reduces weight and heat of raw coal. This loss is described as additional energy use to supplement the lack in the model.

Table J.1. Parameters for coal washing

Coal characteristics	Removal rate (%)	Initial cost ($b_p^{0"}$)		Operating cost ($g_p^{0"}$)		Additional energy use (e_p)
		($/GJ)	($/toe)	($/GJ)	($/toe)	
PA Armstrong	41.3%	0.35	14.7	0.10	4.2	5.3%
OH Jefferson	25.4%	0.34	14.1	0.10	4.2	9.9%
WVA Logan	17.4%	0.33	13.6	0.10	4.2	5.3%
IL NO.6	23.2%	0.37	15.4	0.12	5.0	13.6%
MN Rosebud	25.4%	0.52	21.8	0.14	5.7	2.6%
ND Lignite	45.0%	0.62	25.9	0.16	6.7	1.1%

J.1.2 Lime stone injection

SO_2 reacts with lime to firm calcium sulfate at high boiler temperatures. With using the principle, sulfur dioxide removal rate of 30-60% can be achieved through the limestone addition. SO_2 sorbent such as limestone ($CaCO_3$) or dolomite ($CaCO_3$*$MgCO_3$) is added to the coal pellets fired in stoker boilers or injected into pulverized coal-fired boilers.
Table J.2 shows the limestone injection's parameters estimated with using the value in Cofala and Syri (1998a). It is assumed to estimate fixed cost that the capacity utilization is 5,200 hours per year, boiler size is 10MWth in case below 20MWth, 150MWth in case of 20-300MWth, 500MWth in case over 300MWth, respectively. Operating cost includes the cost of maintenance, administrative overhead, labor cost, sorbent cost and by-product/waste disposal cost, but does not include the cost for increased energy demand. The energy cost is calculated with additional energy use endogenously in the model.

Table J.2. Parameters of limestone injection

Capacity class (MWth)	Fuel for boiler	Removal rate (%)	Initial cost ($b_p^{0''}$)		Operating cost ($g_p^{0''}$)		Additional Energy use (e_p)
			($/GJ)	($/toe)	($/GJ)	($/toe)	
< 20	Brown coal	50%	1.74	72.8	0.15	6.1	0.45%
	Hard coal	50%	1.45	60.7	0.13	5.6	0.45%
	Other solid	50%	1.45	60.7	0.11	4.6	0.45%
	Oil and gas	50%	1.30	54.6	0.13	5.4	0.45%
20-300	Brown coal	50%	2.21	92.7	0.17	6.9	0.45%
	Hard coal	50%	1.85	77.3	0.15	6.3	0.45%
	Other solid	50%	1.85	77.3	0.13	5.3	0.45%
	Oil and gas	50%	1.66	69.5	0.14	6.0	0.45%
> 300	Brown coal	50%	1.81	76.0	0.15	6.3	0.45%
	Hard coal	50%	1.51	63.3	0.14	5.8	0.45%
	Other solid	50%	1.51	63.3	0.11	4.8	0.45%
	Oil and gas	50%	1.36	57.0	0.13	5.5	0.45%

J.1.3 Flue gas desulfurization process

Flue gas desulfurization (FGD) is the chemical process to remove SO_2 from the flue gases. Wet lime or limestone FGD is the representative process of wet FGD. Desulfurization reaction of the process is as follows.

Limestone ; $CaCO_3 + SO_2 \rightarrow CaSO_3 + CaSO_4 + CO_2$
Lime ; $Ca(OH)_3 + SO_2 \rightarrow CaSO_3 + CaSO_4 + H_2O$

The by-product, gypsum, can be used for a variety of industrial applications. Table J.3 shows wet FGD's parameters estimated with using the value in Cofala and Syri (1998a). The assumption in the estimate and the content of fixed / operating cost are same as in case of lime stone injection.Wellman-Lord process is the typical economic and technical properties representative for high-efficiency desulfurization techniques. Desulfurization reaction of the process is as follows.

$$2NaOH + SO_2 \rightarrow Na_2SO_3 + H_2O$$

Table J.4 shows the parameter of Wellman-Lord process as the advanced FGD. This process produces SO_2 rich gas instead of gypsum. The gas can be used as raw input in chemical industry.

Table J.3. Parameters of wet flue gas desulfurization process

Capacity class (MWth)	Fuel for boiler	Removal rate (%)	Initial cost ($b_p^{0''}$)		Operating cost ($g_p^{0''}$)		Additional energy use (e_p)
			($/GJ)	($/toe)	($/GJ)	($/toe)	
< 20	Brown coal	95%	6.05	253.2	0.29	12.2	0.90%
	Hard coal	95%	5.04	211.0	0.25	10.6	0.90%
	Other solid	95%	5.04	211.0	0.24	9.9	0.90%
	Oil and gas	95%	4.54	189.9	0.23	9.7	0.90%
20-300	Brown coal	95%	5.26	220.1	0.26	10.9	0.90%
	Hard coal	95%	4.38	183.4	0.23	9.5	0.90%
	Other solid	95%	4.38	183.4	0.21	8.8	0.90%
	Oil and gas	95%	3.94	165.0	0.21	8.7	0.90%
> 300	Brown coal	95%	4.23	177.3	0.22	9.2	0.90%
	Hard coal	95%	3.53	147.7	0.19	8.0	0.90%
	Other solid	95%	3.53	147.7	0.18	7.4	0.90%
	Oil and gas	95%	3.18	132.9	0.18	7.4	0.90%

Table J.4. Parameters of advanced flue gas desulfurization process

Capacity class (MWth)	Fuel for boiler	Removal rate (%)	Initial cost ($b_p^{0''}$)		Operating cost ($g_p^{0''}$)		Additional energy use (e_p)
			($/GJ)	($/toe)	($/GJ)	($/toe)	
< 20	Brown coal	98%	23.29	974.9	0.94	39.5	1.98%
	Hard coal	98%	19.40	812.4	0.79	33.0	1.98%
	Other solid	98%	19.40	812.4	0.79	33.0	1.98%
	Oil and gas	98%	17.46	731.2	0.71	29.8	1.98%
20-300	Brown coal	98%	12.83	537.3	0.53	22.0	1.98%
	Hard coal	98%	10.69	447.7	0.44	18.4	1.98%
	Other solid	98%	10.69	447.7	0.44	18.4	1.98%
	Oil and gas	98%	9.62	403.0	0.40	16.6	1.98%
> 300	Brown coal	98%	10.12	423.5	0.42	17.5	1.98%
	Hard coal	98%	8.43	352.9	0.35	14.6	1.98%
	Other solid	98%	8.43	352.9	0.35	14.6	1.98%
	Oil and gas	98%	7.59	317.6	0.32	13.2	1.98%

J.2 Removal process for NO_x emission

J.2.1 Removal process for stationary sources

There are two types of removal process for NO_x emission from stationary sources. One is combustion modification and the other is flue gas cleaning. The reduction of excess oxygen levels and peak flame temperature are used as the principles of combustion modification. Low-NO_x burner and fluidized bed combustion fall into the category. Selective catalytic reduction (SCR) is widely applied as flue gas cleaning. Denitration reactions of the process are as follows.

$$4NO + 4NH_2 + O_2 \rightarrow 2N_2 + 6H_2O$$
$$6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$$

Non-selective catalytic reduction (NSCR) needs injection of ammonia or other reducing agents without a catalyst. The reaction is as follows.

$$CO(NH_2)_2 + 2NO + 1/2O_2 \rightarrow 2N_2 + CO_2 + 2H_2O$$

Tables J5 and J.6 show the parameters of removal process for power plant sector and industrial boilers, respectively. They are estimated by using the values in Cofala and Syri (1998b). It is assumed that capacity utilization is 6,000 hours per year, boiler size is 10MWth in case below 20MWth, 150MWth in case of 20-300MWth, 500MWth in case over 300MWth. Operating cost includes the costs of maintenance, overhead, labor, sorbent, catalyst and by-product/waste disposal, but does not include the cost of increased energy demand. Energy cost is calculated endogenously in the model.

Table J.5. Parameters of removal process for power plant sector

Removal process		Removal rate (%)	Initial cost ($b_p^{0"}$)		Operating cost ($g_p^{0"}$)		Additional energy use (e_p)
			($/GJ)	($/toe)	($/GJ)	($/toe)	
Combustion modification (CM)							
< 20	Brown coal	65%	0.81	34.1	0.05	2.0	0.32%
	Hard coal	50%	0.54	22.6	0.03	1.4	0.32%
	Oil and gas	65%	0.29	12.0	0.02	0.7	0.27%
20-300	Brown coal	65%	0.71	29.7	0.04	1.8	0.32%
	Hard coal	50%	0.48	20.0	0.03	1.2	0.32%
	Oil and gas	65%	0.25	10.3	0.01	0.6	0.27%
300 <	Brown coal	65%	0.62	26.1	0.04	1.6	0.32%
	Hard coal	50%	0.40	16.7	0.02	1.0	0.32%
	Oil and gas	65%	0.27	11.4	0.02	0.7	0.27%
Selective catalytic reduction (SCR)							
< 20	Brown coal	80%	1.65	69.3	0.18	7.5	0.32%
	Hard coal	80%	1.38	57.7	0.15	6.4	0.32%
	Oil and gas	80%	0.97	40.5	0.09	3.8	0.27%
20-300	Brown coal	80%	1.32	55.4	0.16	6.7	0.32%
	Hard coal	80%	1.10	46.2	0.14	5.7	0.32%
	Oil and gas	80%	0.78	32.7	0.08	3.3	0.27%
300 <	Brown coal	80%	1.00	42.0	0.14	5.9	0.32%
	Hard coal	80%	0.84	35.0	0.12	5.1	0.32%
	Oil and gas	80%	0.60	24.9	0.07	2.8	0.27%
CM + SCR							
< 20	Brown coal	80%	2.08	87.2	0.19	7.8	0.32%
	Hard coal	80%	1.64	68.8	0.15	6.5	0.32%
	Oil and gas	80%	1.13	47.3	0.09	3.7	0.27%
20-300	Brown coal	80%	1.68	70.4	0.16	6.8	0.32%
	Hard coal	80%	1.33	55.5	0.14	5.7	0.32%
	Oil and gas	80%	0.92	38.4	0.07	3.1	0.27%
300 <	Brown coal	80%	1.30	54.6	0.14	5.9	0.32%
	Hard coal	80%	1.01	42.2	0.12	4.9	0.32%
	Oil and gas	80%	0.75	31.2	0.06	2.7	0.27%

Table J.6. Parameters of removal process for industrial boilers and furnaces

Removal process		Removal rate (%)	Initial cost ($b_p^{0''}$)		Operating cost ($g_p^{0''}$)		Additional energy use (e_p)
			($/GJ)	($/toe)	($/GJ)	($/toe)	
Combustion modification (CM)							
< 20	Solid fuels	50%	0.54	22.6	0.03	1.4	0.27%
	Oil and gas	50%	0.40	16.9	0.02	1.0	0.27%
20-300	Solid fuels	50%	0.48	20.0	0.03	1.2	0.27%
	Oil and gas	50%	0.35	14.6	0.02	0.9	0.27%
300 <	Solid fuels	50%	0.40	16.7	0.02	1.0	0.27%
	Oil and gas	50%	0.28	11.6	0.02	0.7	0.27%
CM + selective catalytic reduction (SCR)							
< 20	Solid fuels	80%	1.64	68.8	0.15	6.2	0.27%
	Oil and gas	80%	1.21	50.5	0.09	4.0	0.27%
20-300	Solid fuels	80%	1.33	55.5	0.13	5.4	0.27%
	Oil and gas	80%	0.98	41.2	0.08	3.4	0.27%
300 <	Solid fuels	80%	1.01	42.2	0.11	4.6	0.27%
	Oil and gas	80%	0.75	31.4	0.07	2.8	0.27%
CM + selective non-catalytic reduction (SNCR)							
< 20	Solid fuels	70%	0.82	34.3	0.10	4.3	0.27%
	Oil and gas	70%	0.59	24.8	0.07	2.7	0.27%
20-300	Solid fuels	70%	0.69	28.7	0.09	3.9	0.27%
	Oil and gas	70%	0.49	20.6	0.06	2.5	0.27%
300 <	Solid fuels	70%	0.55	22.8	0.09	3.6	0.27%
	Oil and gas	70%	0.38	16.1	0.05	2.2	0.27%

J.2.2 Removal process for mobile sources

NO_x emission can be reduced by change in engine design, change in fuel quality after treatment of the exhaust gas by catalytic converters. Table J.7 shows the parameters of removal process for transport sector. They are estimated with using the value in Cofala and Syri (1998b). Operating cost is assumed 11% of fixed cost.

Table J.7. Parameters of removal process for transport sector

Removal process	Removal rate (%)	Initial cost ($b_p^{0"}$)		Operating cost ($g_p^{0"}$)		Additional energy use (e_p)
		($/GJ)	($/toe)	($/GJ)	($/toe)	
Gasoline 4-stroke passenger cars and LDV						
3-way catalytic converter 1992	75%	8.5	358	2.6	107	0
3-way catalytic converter 1996	87%	10.2	429	3.1	129	0
Adv. cnv. with maintenance schemes –EU 2000	93%	24.2	1014	7.3	304	0
Adv. cnv. with maintenance schemes –EU 2005	97%	30.2	1264	9.1	379	0
Diesel passenger cars and LDV						
Combustion modification 1992	31%	5.1	215	1.5	64	0
Combustion modification 1996	50%	9.4	393	2.8	118	0
Adv. CM with maintenance schemes –EU 2000	60%	26.6	1115	8.0	335	0
NO_x converter	80%	35.1	1469	10.5	441	0
Heavy duty vehicles - diesel						
EURO I – 1993	33%	20.5	858	6.1	257	0
EURO II – 1996	43%	61.5	2574	18.4	772	0
EURO III – EU 2000	60%	138.2	5788	41.5	1736	0
EURO IV (NO_x converter)	85%	274.9	11508	82.5	3452	0
Heavy duty vehicle						
Natural gas – catalytic converter	85%	93.9	3933	28.2	1180	0
Gasoline – catalytic converter	85%	93.9	3933	28.2	1180	0
Heavy duty vehicle						
CM + medium vessels	40%	3.9	164	1.2	49	0
CM + large vessels	40%	5.7	237	1.7	71	0
SCR – large vessels	90%	18.0	752	5.4	226	0

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